LBNL-51938

Documentation of Calculation Methodology, Input Data, and Infrastructure for the Home Energy Saver Web Site

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VERSION 1.3

April 2007

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This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technology, State, and Community Programs of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Abstract

The Home Energy Saver (HES, http://HomeEnergySaver.lbl.gov) is an interactive web site designed to help residential consumers make decisions about energy use in their homes. This report describes the underlying methods and data for estimating energy consumption. Using engineering models, the site estimates energy consumption for six major categories (end uses); heating, cooling, water heating, major appliances, lighting, and miscellaneous equipment. The approach taken by the Home Energy Saver is to provide users with initial results based on a minimum of user input, allowing progressively greater control in specifying the characteristics of the house and energy consuming appliances. Outputs include energy consumption (by fuel and end use), energy-related emissions (carbon dioxide), energy bills (total and by fuel and end use), and energy saving recommendations. Real-world electricity tariffs are used for many locations, making the bill estimates even more accurate. Where information about the house is not available from the user, default values are used based on end-use surveys and engineering studies. An extensive body of qualitative decision-support information augments the analytical results.

Acknowledgements

This project has been many years in the making, and has benefited from the expertise of many people. The tasks have ranged from creating the models and gathering the data documented in this report to building and maintaining the user interface and underlying code base. The entire development team is listed below:

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1. Introduction

The Home Energy Saver (HES, http://HomeEnergySaver.lbl.gov) is an interactive web site designed to help residential consumers make decisions about energy use in their homes. Its aims are to increase consumer interest in energy efficiency and to foster market activities that capture those opportunities. The site is developed and maintained by the Lawrence Berkeley National Laboratory with sponsorship (past and/or present) from the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the California Energy Commission.

Development of the Home Energy Saver began in 1994, and the site first went on-line in 1996[1], originally sponsored by the ENERGY STAR program, operated by EPA and DOE (Mills 1997)[2]. The Home Energy Saver uses state-of-the-art data and models to support the Federal energy mission by helping to build national recognition of Federal energy efficiency programs and by enabling consumers to quantify the energy savings and environmental benefits that can be achieved by improving the energy efficiency of their home. The site is also used periodically by researchers, designers and contractors as a tool for analyzing residential energy performance issues, and for learning from actual homeowners about their experiences with implementing energy-saving upgrades. Finally, through the Energized Learning module, science educators at the high school and college level regularly use HES as part of their science curricula (http://EnergizedLearning.lbl.gov). As of August 2004, there are approximately 460,000 top-page visits per year. Based on a user-feedback form, submitted thus far by approximately 1100 users, approximately 80% of users are homeowners or renters, with the balance made up of those who visit for professional/educational reasons, such as building professionals, educators, contractors etc.

The Home Energy Saver provides two basic services to the residential consumer

- A calculation of energy consumption by end use, for the entire household
- Estimate of energy bills based on end use consumption, and a comparison of consumption to a "typical" household and subsequent recommendations for bill reduction.

In this report, we first provide a description of the method for calculating energy consumption, and the levels of input detail available to the user and the output reported to the user. We then describe the calculation of energy bills based on consumption. Finally, we document the presentation by which consumers can compare results for their household to households typical in their geographical area, and which suggest possibilities for energy bill reduction. The report includes appendices that describe the user interface and software/hardware architecture underlying the site[3].

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[1] An earlier version developed at LBNL was called WebCalc.

[2] In 2000, the ENERGY STAR program sponsored the development of a simplified consumer web site derived from the HES, called Home Energy Advisor (Advisor, http://hit.lbl.gov). In most cases, Advisor uses the same data and calculation methodologies as HES, but employs a more constrained building description and provides different outputs

[3] A companion report (Warner 2005) describes the use of the DOE-2.1E simulation model for handling space conditioning.

The goal in developing the Home Energy Saver web site has been to provide consumers with a simple way to use state-of-the-art residential energy calculation tools and energy data. The site integrates a variety of models, algorithms, and data sources developed over several decades at Lawrence Berkeley National Laboratory, other DOE National Labs, utilities, and elsewhere in the energy community. Historically, access to and use of such materials has required more extensive expertise and knowledge of energy and building technologies than that possessed by consumers. Making these tools and information available via a web-based interface, enables lay users to obtain energy use and savings estimates tailored to their particular home, climate, lifestyles, etc. While not discussed further here, the site also provides extensive "decision-support" information to accompany the analytical results (via the "Librarian" and "Making it Happen" modules).

Consumer-oriented home energy calculators are most effective if they combine careful energy analysis with energy cost information in a fashion that yields meaningful energy bills. Energy tariffs (particularly those for electricity) are becoming increasingly complex, as they are redesigned to encourage efficient use of energy at the margin and management of peak demand. For example, the so-called "inverted block tariffs" present the user with an increasing per-unit electricity price as consumption rises. "Time-of-Use" tariffs present the user with high electricity prices at times when the utility system is likely to be facing peak demands (e.g. weekday afternoons during summer), and correspondingly low prices at off-peak times. Most energy calculators utilize highly stylized prices (e.g. a flat cents-per-kilowatt-hour value), which fail to capture the real-world conditions facing consumers. To address this void, the Home Energy Saver site includes a process to model electricity bills using actual utility tariffs.

1.1. Limitations and Advantages of Web-based Energy Modeling

- State – Unlike a computer based application, the web based environment does not maintain a constant connection between a user and the application. For each new action, the web server must be given information to connect a user with their particular session, in the form of cookies or a session ID. If this information expires, the user is required to start the process over.
- Network Latency and Errors – the internet is a conglomeration of servers, routers and transmission paths that are largely independent of each other. Delays or lack of service in any part can make it appear to a user that our site is unavailable or slow. To a great extent, the internet compensates for outage and bottlenecks by re-routing traffic to areas with greater capacity, but some bottlenecks can't be avoided, such as the link from the user's computer to their ISP.
- User comprehension – energy modeling is a complex process, and has its share of technical language. We've attempted to use common language in parsing inputs and results, but misunderstandings and confusion can still occur. The lack of a trained professional on hand to assist may limit some users experience.

Advantages include ease of distribution, version control, platform independence and the ability to locate computation-intensive simulation engines such as DOE-2 on a central (free to the public) server, rather than requiring users to install and administer them on home personal computers.

2. User Interface

The Home Energy Saver was the first Internet-based tool for calculating energy use in residential buildings. The approach taken by the web site is to provide users with results based on a minimum of user input, and then, for those interested in continuing, allowing them progressively greater degrees of control in specifying the house and energy consuming appliances characteristics. This allows users with limited knowledge or time to access results that are generally applicable to their situation, while more informed or persistent users can get greater accuracy and relevance by customizing their house description. This design philosophy results in a progressive three-tiered approach to estimating energy consumption.

At the initial level of inputs, users are asked solely for their zip code (Figure 1). An initial set of results are immediately derived from the zip code input. These results are averages for the housing stock in their region, based on the 2001 Residential Energy Consumption Survey (RECS) (US DOE. 2004). HES also presents potential savings for a typical house in that region.

Simultaneously, users are shown the questions for the second, “simple inputs” level of the Home Energy Saver (Figure 2). This set of questions focuses on those appliances and housing characteristics that cause large variance in energy consumption (e.g. floor area, heating equipment, etc.). These key inputs can be used to refine the energy estimation further.

After answering the questions in the “simple inputs” level of HES, users can either calculate the energy used by their house based on the description provided by the “simple level” of questions or further refine the house description before calculating by accessing the third, “detailed inputs” level of the model (Figure 4). In the detailed input pages, they can adjust nearly all of the envelope, site and appliance characteristics that go into estimating energy consumption for their home (Figure 3).

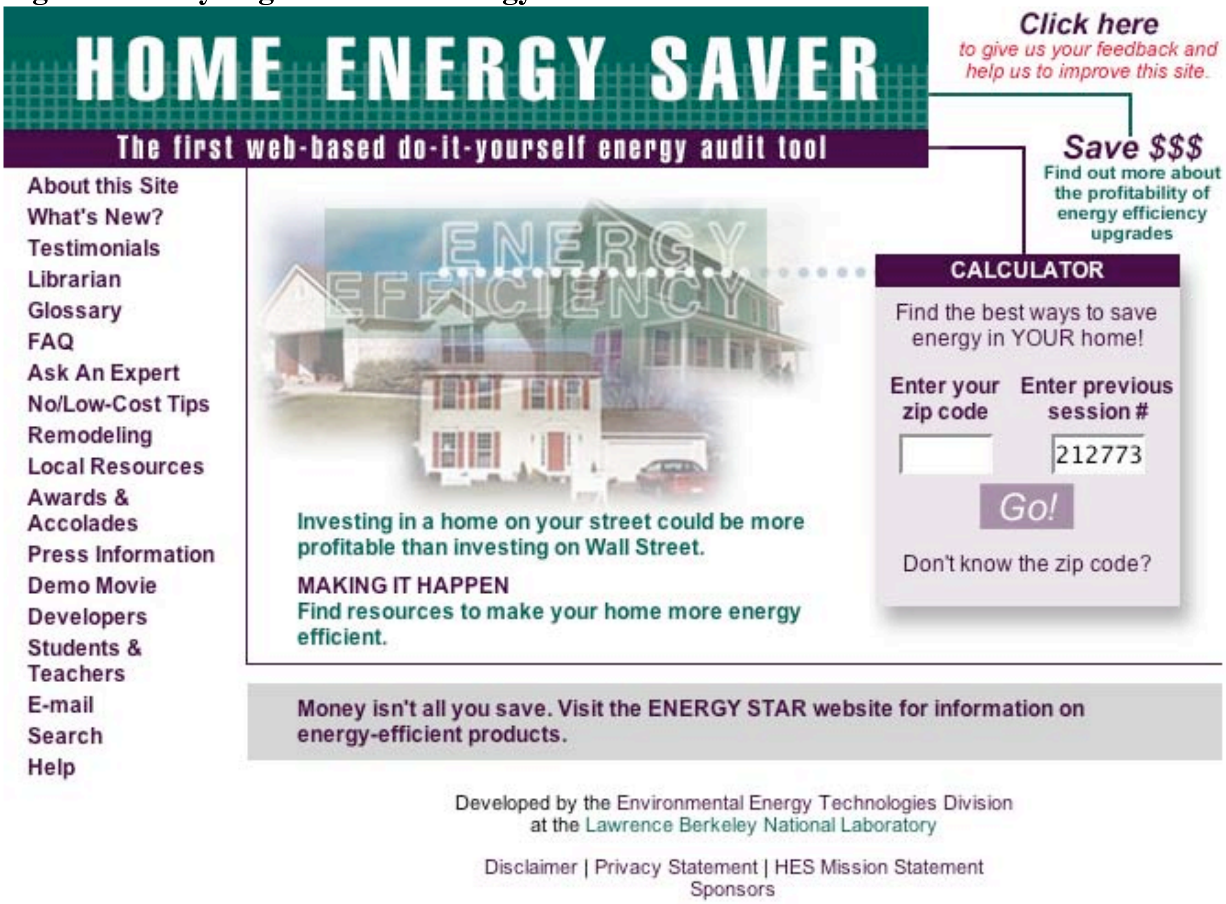
When the user is satisfied with the house description, they calculate the energy consumption (Figure 5), which replaces the prior default results based on a house in their area. At this time they can also view more detailed reports about their home's energy consumption (Figures 6 and 7).

For both the “simple inputs” and “detailed inputs” levels, the models used to estimate energy consumption are identical, with user-entered values substituting for default values as the user progresses through the “detailed inputs” level. There are six major categories (end-uses) where energy consumption is estimated; heating, cooling, water heating, major appliances, lighting, and miscellaneous equipment. The Home Energy Saver uses engineering models to estimate energy consumption for all these end-uses.

2.1 Entry Page

The entry point to the calculation process is through the main page of the Home Energy Saver website. In addition to all of the informational content about energy efficiency, the users can choose to enter their ZIP code and initiate a session, or enter their session number from a previous visit, which will return them to the results of that session.

Figure 1. Entry Page for Home Energy Saver Website



2.2. Initial "Simple" Inputs Page with ZIP Code Based Bill

After entering a zip code, the users see the first page, which shows the average energy consumption for a typical house in their area, taken from the Residential Energy Consumption Survey (RECS) (US DOE 2004), see Section 4.1 for details on how this average bill was generated. The lower half of the screen shows the questions for the "simple" level of calculation (Figure 2). Users have the choice of calculating the bill for their house, based on those questions, or providing more detail about their house before calculating. By answering the detailed questions (Figure 3), users get results calculated using a house description that more closely matches their house.

Figure 2. Initial "Simple" Inputs Page with ZIP Code Based Bill

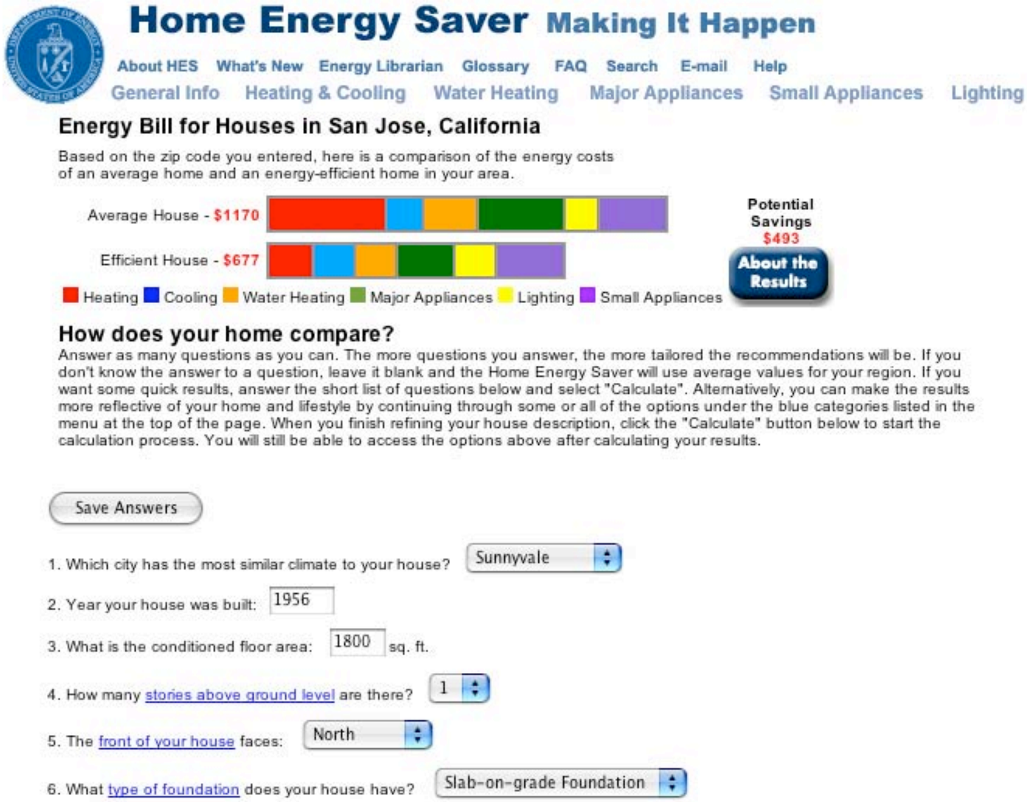


Figure 3. Sample Detailed Input Page (Energy Prices)

2.3. Error Handling

2.3.1 User Input Validations

Where appropriate, the user interface is designed with javascript and occasionally using server-side input validations to ensure that the answer submitted by the user is valid. There are two main types of javascript validations, the first prevents non-valid characters from being typed into text boxes (e.g. alphabetic characters not allowed in an integer text field), while the second checks the final value against the allowable range (e.g. percentage values must be between 0% and 100%). Additionally in a few instances, there are server side validations that check inputs for more complicated problems (e.g. window area is greater than wall area when framing members and area of doors is included). When an error is noted, a message is displayed to the user, identifying the problem and asking them to correct their inputs.

2.3.2 Failures in the DOE-2.1 Calculation

On occasion, a dropped network connection or an inappropriate house description can cause the DOE-2 engine to experience failure. The Home Energy Saver has error traps in place to prevent the loss of data in a situation where there is a DOE-2 failure. After the results of the DOE-2 run are returned to the web application, the returned energy consumptions are tested for valid values. If an error is detected, the web application discards the returned values, continuing the calculation with the previous energy consumptions for heating and cooling. If results are not returned from DOE, the application again reverts to previously stored data.

2.4. Results Page

After the energy calculations are complete, users are presented with a new page showing the results of the calculation (Figure 4). The top half of the page now contains results generated from their house description (rather than a typical house in their area). The bottom half of the page shows a list of possible retrofits for their house, based on the current house description, as well as links to other reports about their energy use and information on how to save energy. Subsidiary pages show monthly energy use by major end use and electricity by time-of-use (TOU) period (for cases where the user has specified a TOU tariff (Figure 5).

Figure 4. Results of Home Energy Saver Calculation

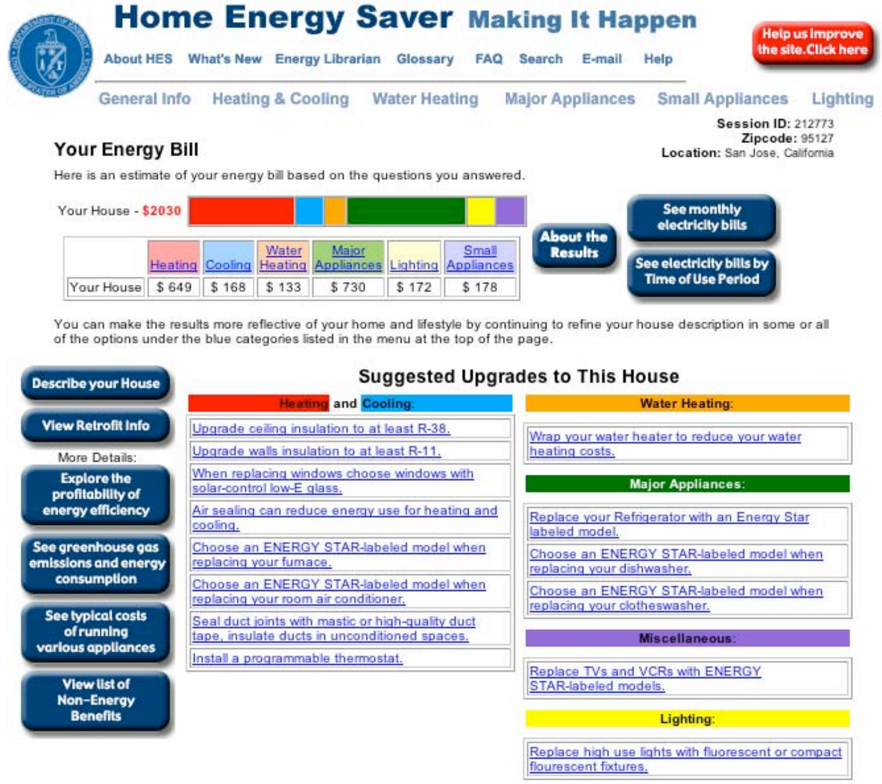
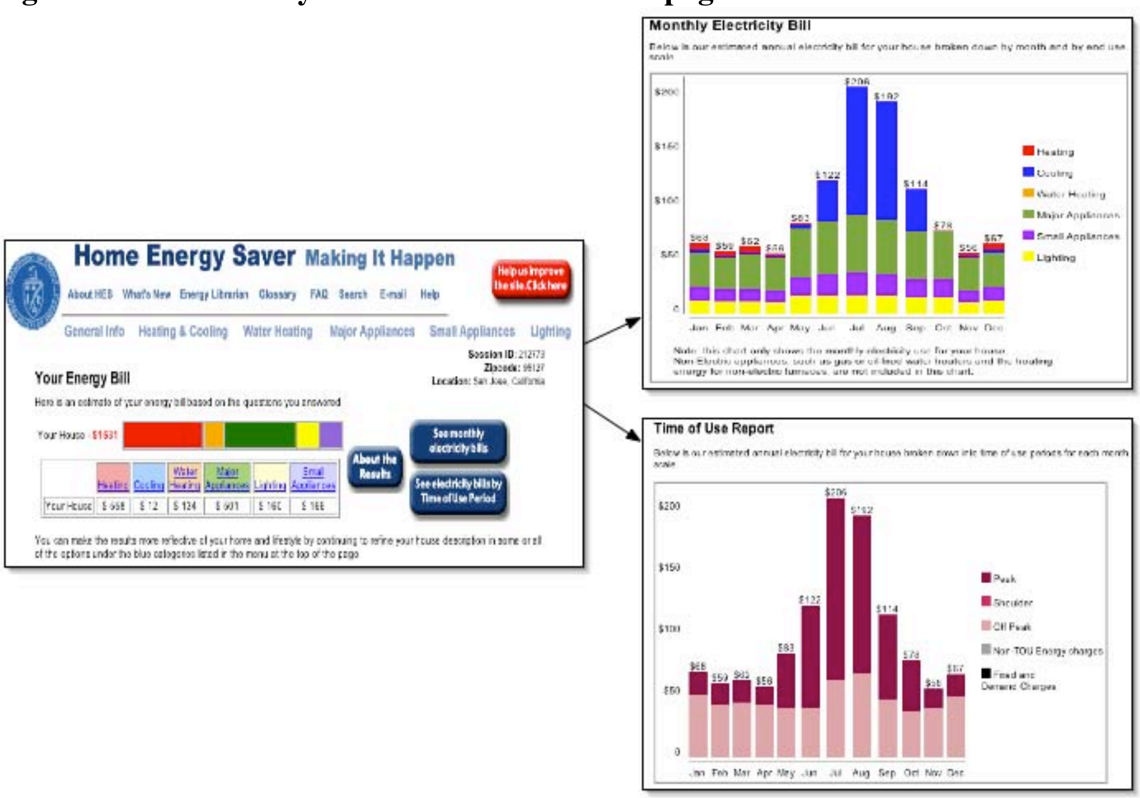


Figure 5. HES Monthly and Time-of-Use Results pages



2.5 Summary Reports

Additional detail is provided on the Summary Report pages. This is where detailed information, such as carbon emissions (Figure 6) or the energy consumption and bill attributable to a single appliance can be found (Figure 7).

Figure 6. Sample Summary Report (Carbon Emissions)

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Detail of Whole House Annual Energy Use

		Base Case	Energy Efficient House
Whole House	$	$1712	$962
	Energy	14378 kWh & 629 Therms	8896 kWh & 261 therms
	Pollution	30716 lb. CO_2	17171 lb. CO_2
Heating	$	$345	$126
	Energy	410 kWh & 367 Therms	136 kWh & 122 therms
	Pollution	4954 lb. CO_2	1645 lb. CO_2
Cooling	$	$400	$149
	Energy	4882 kWh	1816 kWh
	Pollution	7935 lb. CO_2	2952 lb. CO_2
Hot Water	$	$178	$90
	Energy	210 Therms	106 therms
	Pollution	2453 lb. CO_2	1235 lb. CO_2
Major Appliances	$	$395	$256
	Energy	4279 kWh & 52 therms	2781 kWh & 34 therms
	Pollution	7562 lb. CO_2	4575 lb. CO_2
Lighting	$	$106	$53
	Energy	1290 kWh	645 kWh
	Pollution	2097 lb. CO_2	1048 lb. CO_2
Misc.	$	$288	$288
	Energy	3517 kWh	3517 kWh
	Pollution	5716 lb. CO_2	5716 lb. CO_2

Figure 7. Energy Consumption and Bill by End-Use (Appliances and Water Heating)

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Appliance and Water Heating Consumption

Here is the approximate energy consumed in a typical year, by your major appliances.

Appliance	Appliance Energy		Water Heating Energy			Total Energy	Total Cost
	Energy per Year	Cost per Year	Water Use (gal/day)	Energy per Year	Cost per Year		
First Refrigerator:	2560 kWh	$ 342	none	none	none	2560 kWh	$ 342
Stove:	365 kWh	$ 49	none	none	none	365 kWh	$ 49
Oven:	239 kWh	$ 32	none	none	none	239 kWh	$ 32
Clothes Dryer:	1456 kWh	$ 194	none	none	none	1456 kWh	$ 194
Clotheswasher	98 kWh	$ 13	21	86 therms	$ 61	98 kWh & 86 therms	$ 75
Dishwasher Total	162 kWh	$ 22	6	25 therms	$ 18	162 kWh & 25 therms	$ 39
Hot Water: Taps and Faucets	none	none	45	186 therms	$ 133	186 therms	$ 133
Totals	4880 kWh	$ 651	72 gallons	296 therms	$ 212	4880 kWh & 296 therms	$ 784

Appliance energy is the energy used by motors, heating elements and burners inside your appliances. This number excludes the energy consumed by your water heater to supply hot water for appliances such as clothes washers and dishwashers.

What if my results don't match my energy bill?

3. Calculation of Energy Consumption

For both the "simple inputs" and "detailed inputs" levels, the models used to estimate energy consumption are identical, with user-entered values substituting for default values as the user progresses through the "detailed inputs" level. There are six major categories (end-uses) where energy consumption is estimated; heating, cooling, water heating, major appliances, lighting, and miscellaneous equipment. The Home Energy Saver uses engineering models to estimate energy consumption for all these end-uses.

Table 1. Comparison of "Simple Inputs" Level vs. "Detailed Inputs" Level

Major End-Use	Simple Inputs Level	Detailed Inputs Level
Heating and Cooling	City with similar climate House construction year Conditioned floor area Stories above ground level Orientation Foundation type Ceiling/floor/wall insulation Heating/cooling equipment Window area (each side of house) Number of occupants in age groups (also affects water heating)	Approximately 80 additional questions about house shape & size; exterior shading; air-tightness; foundation & floor; walls; doors & windows; skylights; attic & roof; ducts & boiler pipes; thermostat details; heating & cooling equipment (efficiency, vintage, etc.)
Water Heating	Water heater fuel	Eight additional questions about temperature settings, water heater location and specifics, etc.
Major Appliances	Number of refrigerators (1-3) Number of freezers (0-2) Presence of clothes washer	Specific details about the refrigerators and freezers specified in the simple level; 8 questions about cooking and your dishwasher; 5 questions about clothes washers/dryers; 8 questions about hot tubs, spas and pumps
Lighting	No questions	Two levels – 1st asks for the number of fixtures/room, energy consumption/fixture defaulted based on TPU study, 2nd asks for detains on the number of bulbs, bulb type, total wattage and usage for each fixture.
Small Appliances	No questions	Roughly 50 questions about entertainment, home office, misc. kitchen appliances and other appliances.

The Home Energy Saver utilizes data from a variety of sources to provide default input values and energy consumption. The bulk of the data compilation for the Home Energy Saver was completed in 1997-1999, and the most current data available at that time was used. For time-sensitive series such as equipment efficiencies, the final data point has been used to provide values for subsequent years. The only exception to this is for the state energy prices, which have been updated to use the most current data available at the time of this report.

3.1 Heating and Cooling Calculation

This section deals with the determination of heating equipment efficiencies, thermal distribution (air or hydronic) efficiencies, infiltration, and thermostat management. The energy consumption for most types of heating and cooling equipment is estimated using the DOE-2 building simulation program (version 2.1E), developed by the U.S. Department of Energy (Birdsall et al., 1990). A companion report (Warner 2005) describes the thermodynamic modeling of the home, and the relevant characterizations of the building's thermal envelope (windows, insulation, etc.) The program performs a sophisticated series of calculations, modeling the energy consumption in the user's house in a full annual simulation for a typical weather year (involving 8760 hourly calculations). Users can choose from approximately 285 weather locations around the United States. Energy use for some heating and cooling equipment types are estimated independently of DOE-2 and are documented in this report. Interactions between space-conditioning equipment and the waste heat from occupants and appliances are also treated in the modeling process.

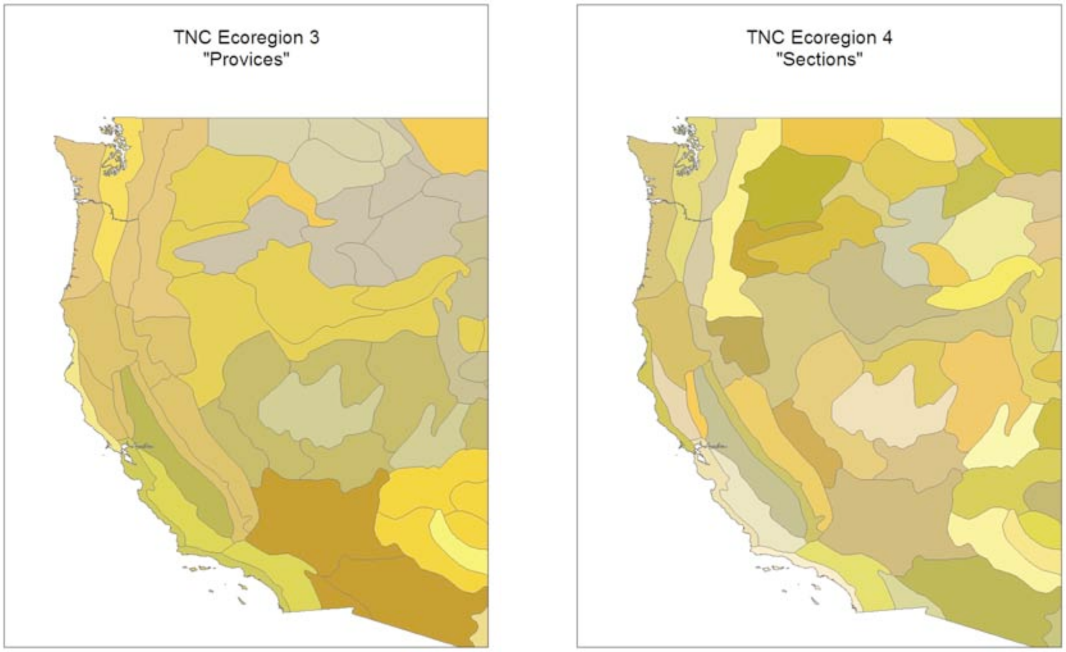
User inputs (or defaulted values, where user-entered values aren't available) are gathered together and sent to the DOE 2.1E model to calculate the heating and cooling (and water heating if user specified that water heating was tied to a central boiler system) energy consumption. The DOE 2.1E model requires inputs on the location (longitude, latitude, altitude, etc.) and climate (a specified "weather city" corresponding to a TMY, TMY2 or CTZ weather tape) of the house; general information about the house (orientation, stories above ground level, ceiling height, house shape and dimensions, etc.); construction details about the house (roof/ceiling/wall/floor/foundation construction details; type, size, shading and location of windows, skylights and doors; external shading (garage location, size of surrounding trees); details on the heating and cooling equipment (equipment type, efficiency, duct location, thermostat type and settings); and information about occupants and other sources of internal gains.

3.1.1 Climate Modeling

When users enter their ZIP code, they are assigned a default city to provide a weather data file for DOE-2 modeling. This assignment was done using a geographic information system (GIS) analysis to locate ZIP codes that are "closest" to cities with associated weather data (Weather Cities). These Weather Cities are listed in Appendix C. To represent the climatic variation across the U.S., we used The Nature Conservancy (TNC) "Ecoregions" (TNC 2001) to associate each Zip Code with an appropriate Weather City based on climate and environment, as well as linear distance.

The Nature Conservancy has created a set of GIS layers delineating EcoRegions on four different scales. The two smallest scales — the Province and the Section — were used in this analysis. These EcoRegions describe areas with relatively homogeneous environmental factors such as temperature, precipitation, humidity, vegetation, and landscape features. While not all these factors are directly related to building energy use, the predominant factors are climate-related and thus highly correlated with building energy use. On visual inspection, we also chose to use the EcoRegions because they correlate well with other climate regions used in energy analysis (e.g., the CEC climate zones) and are available nationally at a fine spatial scale. See Figure 8 for examples of the EcoRegions used in this analysis. See http://www.fs.fed.us/institute/ecolink.html for further description of the ecoregion concept. ZIP code boundary data were obtained from the U.S. Census Bureau (2004)

Figure 8: Example EcoRegions in the Western U.S.



Source: . (TNC 2001).
Note that Sections (right) are subdivisions of Provinces (left).

To assign ZIP codes, we found the closest Weather City that is also within the same Ecoregion as that ZIP code. For each ZIP code, we first tried to do this matching at the Ecoregion "Section" (smallest scale) level, but if there was no matching Weather City we would then match at the Province level. If no match was possible at the Province level, we simply used the closest weather city (in geographic distance). Distances were based on ZIP code centroid to city center. Finally, the matches were reviewed and adjusted manually.

For use in modeling water heating energy consumption, we estimate the annual average inlet water temperature (from the domestic water system) by subtracting 2˚F from the annual average dry-bulb air temperature reported in the weather data files. Inlet water temperatures in Alaska were constrained to be greater than 32 degrees Farenheit. These values are listed in Appendix C.

Summary weather statistics for each weather data file were calculated using the DOE-2 weather packing routines. These summary statistics include seasonal heating and cooling degree-days, winter and summer design-day conditions, and weather-station location data. DOE-2 utilizes the full TMY2 weather tape, extracting solar gains (insolation) and other needed information for use in the annual simulation.

3.1.2 Default House Characteristics

To assist users with describing the characteristics of their house, when users first enter the Home Energy Saver site, they are assigned default house characteristics based on the Census Division in which their ZIP code is located. These default characteristics were developed by analyzing the 1993 and 2001 Residential Energy Consumption Survey (RECS) microdata[4] (US DOE 1995a, US DOE 2004). Consumption and characteristics are based on RECS 2001 supplemented by lighting and electrical cooking consumptions from RECS 1993. All analysis is based on a subset of homes; mobile homes and single family homes (both attached and unattached). Where a house characteristic can only have discrete values (e.g., type of heating fuel or presence of dishwasher), we tabulated the saturation of that characteristic in the RECS data set and selected the most common value. For example, if natural gas was the most common heating fuel in a region, then the default house is assumed to use natural gas for heating. Appendix A. Default House Characteristics contains the default input values for each census division. For the remaining characteristics for the house, a single value was applied across all divisions. Table A-2 contains these nation-wide default housing characteristics. Default house shell characteristics, for use in DOE-2, are described in the DOE-2 companion report (Warner 2005).

3.1.3 Heating and Cooling Equipment

The Home Energy Saver web site models the following heating and cooling equipment types:

Table 2. Heating and Cooling Equipment

Equipment Type	Calculation	Default Efficiency*	Default Capacity	Default Usage
		Heating		
Central Gas furnace	DOE-2	78	**	***
Room (through-the-wall) Gas furnace	DOE-2	65.6	**	***
Propane (LPG) furnace	DOE-2	78	**	***
Oil furnace	DOE-2	80	**	***
Electric furnace	DOE-2	98	**	***
Electric heat pump (heating)	DOE-2	7.0 HSPF	**	***
Electric baseboard heater	DOE-2	98	**	***
Gas boiler	DOE-2	80	**	***
Oil boiler	DOE-2	80	**	***
		Cooling		
Central air conditioner	DOE-2	9.5 SEER	**	***
Room air conditioner	$\left(\frac{\left(\frac{capacity \times hours/day \times days/year}{efficiency}\right)}{1000}\right) \times 0.003412$	9.0 EER	13,000 Btu/hr	Hrs/day=5, Days=99
Electric heat pump (cooling)	DOE-2	9.5 SEER	**	***
Whole house fan	$power_{fan} \times hours/day \times 30 \times months$	$power_{fan}$=0.3 kWh; hours/day=2; months=2		
Ceiling fan	$50kWh \times number_{fans}$	$Number_{fans}$=2		
Portable fan	$22kWh \times number_{fans}$	$Number_{fans}$=2		

[4] Microdata are the household-level data from each of the houses in the RECS sample.

*Default Efficiency is AFUE unless otherwise indicated.
** Capacity for this equipment type is automatically calculated in the DOE-2.1 model.
*** Usage for this equipment type is calculated in the DOE-2.1 model, based on user-specified thermostat settings and schedule (see below)
Note: DOE-2.1 models both electricity and other fuel usage for equipment types with multiple fuels (e.g. Central Gas Furnaces, which use natural gas for heating and electricity use by the air-handler fan).

For those equipment types modeled in DOE-2, the equipment characteristics (default values taken from Table 1) are input to the DOE-2 model. Energy consumption in million BTUs is returned from DOE-2 and converted to the units in which the consumer would purchase the fuel, using the fuel-specific conversion factors found in Table 3.

Table 3. Fuel Conversion Factors – MBtu to consumer-purchasing units

Fuel	Conversion factor (site energy)
Electricity	3412.76 kWh/MBtu
Natural Gas	100,000 therms/MBtu
Liquid Propane	91,500 gallons LPG/MBtu
Fuel Oil	138,690 gallons oil/MBtu

3.1.3.1 Heating Equipment Efficiency

In the detailed inputs level of the model, users can select the purchase year for their heating and cooling systems as an alternative to entering an efficiency value for the equipment. In these cases, we derive a shipment-weighted efficiency based on the purchase year of the equipment (Table 4 and Table 5). A shipment-weighted efficiency is the average efficiency for all units sold within a particular year weighted by the number of units in each efficiency bin (AHAM 1996). Efficiencies for furnaces are measured as AFUE, or Annual Fuel Utilization Efficiency rating, which represents the seasonal or annual efficiency of the furnace. Heat pumps efficiency is shown as HSPF, Heating Seasonal Performance Factor.

Table 4. Shipment Weighted Efficiencies for Heating Equipment

Year	Electric Furnace (AFUE)	Electric Heat Pump (HSPF)	Gas Boiler (AFUE)	Gas Furnace (AFUE)	Gas Wall Furnace (AFUE)	Oil Boiler (AFUE)	Oil Furnace (AFUE)	Propane Furnace (AFUE)
1970	98	5.5	70	60	50	72	70	60
1972	98	6.21	72.3	62.7	59.5	75.2	73.6	62.7
1973	98	6.21	72.3	62.7	59.5	75.2	73.6	62.7
1974	98	6.21	72.3	62.7	59.5	75.2	73.6	62.7
1975	98	6.21	72.3	65.825	59.5	75.2	73.6	65.825
1976	98	6.87	72.3	66.12133333	59.5	75.2	74.1	66.12
1977	98	6.89	72.3	66.41766667	59.5	75.2	74.5	66.42
1978	98	7.24	72.3	66.714	59.5	75.2	75	66.71
1979	98	7.34	72.3	68.6565	59.5	75.2	75.5	68.66
1980	98	7.51	72.3	70.599	59.5	75.2	76	70.60
1981	98	7.7	77.4	70.441	63.1	77.4	76.8	70.44
1982	98	7.79	77.4	70.283	63.1	77.4	77.5	70.28
1983	98	8.23	77.4	70.125	63.1	77.4	78.3	70.13
1984	98	8.45	77.4	72.61795	63.1	77.4	78.6	72.62
1985	98	8.56	77.4	72.8865	63.1	77.4	78.6	72.89
1986	98	8.7	78.2	73.7325	64.2	81.6	79.6	73.73
1987	98	8.93	78.2	74.3305	64.2	81.6	79.8	74.33
1988	98	9.13	78.2	74.86195	64.2	81.6	80.4	74.86
1989	98	9.26	79.7	74.673	65.6	83.1	80.4	74.67
1990	98	9.46	79.7	76.70038	65.6	83.1	80.3	76.70
1991	98	9.77	79.7	77.53506	65.6	83.1	80.8	77.54
1992	98	10.6	79.7	82.075255	65.6	83.1	80.8	82.08
1993	98	10.86	79.7	82.40836	65.6	83.1	80.9	82.41
1994	98	10.94	79.7	82.433065	65.6	83.1	80.9	82.43
1995	98	10.97	79.7	82.33027	65.6	83.1	80.9	82.33
1996	98	11	79.7	82.65663	65.6	83.1	80.9	82.663
1997	98	10.97	79.7	82.86116	65.6	83.1	80.9	82.86
1998	98	11.29	79.7	82.61708	65.6	83.1	80.9	82.62
1999	98	11.29	79.7	82.63403	65.6	83.1	80.9	82.62
2000	98	11.21	79.7	82.620087	65.6	83.1	80.9	82.62
2001	98	11.3	79.7	83.15	65.6	83.1	80.9	82.62
2002	98	11.31	79.7	83.15	65.6	83.1	80.9	82.62
2003	98	11.31	79.7	83.15	65.6	83.1	80.9	82.62

Source: GAMA 2002, GAMA 2003
Note: Furnace fan efficiencies are handled in the heating and cooling model, and are documented in the companion report (Warner 2005).
Cells with yellow shading have data extended from previous data point.

3.1.3.2 Cooling Equipment Efficiencies

The cooling efficiency for Central Air Conditioners and Electric Heat Pumps are rated by the seasonal efficiency of the equipment or SEER. Room Air Conditioners are rated by EER or Energy Efficiency Ratio, the ratio of the cooling output (in BTU) divided by the electrical energy consumption (in watt-hours).

Table 5. Shipment Weighted Efficiencies for Cooling Equipment

Year	Central Air Conditioner (SEER)	Electric Heat Pump (SEER)	Room Air Conditioner (EER)
1970	6.5	5.5	5.8
1972	6.66	6.21	5.98
1973	6.75	6.21	6
1974	6.85	6.21	6.1
1975	6.97	6.21	6.2
1976	7.03	6.87	6.4
1977	7.13	6.89	6.55
1978	7.34	7.24	6.72
1979	7.47	7.34	6.87
1980	7.55	7.51	7.02
1981	7.78	7.7	7.06
1982	8.31	7.79	7.14
1983	8.43	8.23	7.29
1984	8.66	8.45	7.48
1985	8.82	8.56	7.7
1986	8.87	8.7	7.8
1987	8.97	8.93	8.06
1988	9.11	9.13	8.23
1989	9.25	9.26	8.48
1990	9.31	9.46	8.73
1991	9.49	9.77	8.8
1992	10.46	10.6	8.88
1993	10.56	10.86	9.05
1994	10.61	10.94	8.97
1995	10.68	10.97	9.03
1996	10.68	11	9.08
1997	10.66	10.97	9.09
1998	10.92	11.29	9.08
1999	10.96	11.29	9.07
2000	10.95	11.21	9.3
2001	11.07	11.3	9.63
2002	11.07	11.31	9.75
2003	11.07	11.31	9.75

Values remain at 2003 levels for subsequent years. Cells with yellow shading contain data from previous year.
Sources: Central Air Conditioner and Electric Heat Pump (ARI 2003), Room Air Conditioner (AHAM 2003).

3.1.3.3 Room Air Conditioner Consumption

Room air conditioners tend to be operated not by central thermostatic control, but rather in a manual mode where the room occupant turns the air conditioner on and off depending on room temperature and occupancy. These complex operating patterns are difficult to model with thermal simulation models such as DOE-2. For this reason, we chose to use a simpler method for estimating room air conditioner energy consumption, based on the AHAM (Association of Home Appliance Manufacturers) test procedure. This method is summarized in Equation 1.

$$UEC = \frac{days \times \frac{hours}{day} \times capacity}{EER} \qquad \textbf{Equation 1}$$

Where

UEC	=	Unit energy consumption (kWh/year)
days	=	Average annual days of room air conditioner operation (days/year)
hours/day	=	Average daily hours of room air conditioner operation (hours/day)
capacity	=	Rated capacity of the room air conditioner (Btu/hour)
EER	=	Energy-efficiency ratio (Btu/kWh)

Because cooling loads and usage vary with climate, we estimate a default *days* and *hours/day* value for each of the cities for which we had weather data (Appendix C-1). We estimate the default daily operating hours using equation 2. These values are rounded to the nearest integer. Climate data used in this equation are drawn from the typical meteorological year (TMY2) weather tapes (Marion and Urban 1995). The first term in equation 2 accounts for the severity of the climate, in terms of dry bulb temperature, while the second term accounts for how humid the climate is. Note that the humidity term is assumed to equal zero for locations above 40°N latitude. The parameters in equation 2 were estimated heuristically so as to yield results that looked reasonable across a range of climates.

$$hours = \frac{2}{5} \times (\mathrm{temp}_{db} - 80) + 20 \times (1.5 - \frac{\mathrm{temp}_{db}}{\mathrm{temp}_{wb}}) \qquad \textbf{Equation 2}$$

Where

temp_{db}	=	Drybulb temperature at cooling design-day conditions (°F)
temp_{wb}	=	Wetbulb temperature at cooling design-day conditions (°F)

We then derive a value for annual RAC compressor hours from the AHAM test procedure manual (AHAM 1982). We used the value corresponding to 66% of full-load, to account for some cycling that occurs in normal room air conditioner operation (These values are shown in Appendix C-1. Where one of our weather cities was not listed in the AHAM document, the Cooling Load Hour value shown in Appendix C-1 is extrapolated from the geographically closest city, using the TMY2 cooling-degree hours at 74° F as a scaling factor.

Finally, the average days per year of operation is simply the ratio of annual compressor hours to the average daily hours of operation.

Room air conditioner capacity is either input by the user or a national-average typical value is used (12,000 Btu/hour). EER is also either user-entered or drawn from the shipment-weighted average for the year in which the air conditioner was sold (as specified by the user).

3.1.4 Thermostats and Thermostat Schedules

The Home Energy Saver is capable of modeling both standard and programmable thermostats. The default thermostat assigned to a new session is a standard thermostat with the default schedule and temperature settings outlined in Table 6. Users can adjust the temperature and time schedules for the two periods (day and night), and can specify a separate schedule for weekdays and weekends/holidays.

Table 6. Default Thermostat Schedule for Standard Thermostats

		Temperature (˚F)	
	Hour	Heating	Cooling
Day	8:00 AM	68	78
Night	5:00 PM	64	81

Alternatively, users can choose a programmable thermostat, which defaults to the schedule outlined in Table 7. As with a standard thermostat, users can specify alternate times and temperatures for the four periods, to differentiate between weekday and weekend/holiday schedules.

Table 7. Default Thermostat Schedule for Programmable Thermostats

		Temperature (˚F)	
	Hour	Heating	Cooling
Wake	7:00 AM	64	78
Leave	9:00 AM	64	78
Evening	7:00 PM	68	81
Sleep	11:00 PM	68	81

The thermostat schedule is sent as an input to the DOE-2 calculation engine where it is used in calculating energy consumption by the heating and cooling equipment.

3.1.5 Internal Gains

Anything producing heat as a waste product affects the heating and cooling loads within the house. The waste heat causes an increase in the cooling energy consumption, and a decrease in the heating energy consumption. The Home Energy Saver accounts for internal gains by passing information about internal heat loads to the DOE-2 building simulation engine. Information about the number of occupants and the energy consumption for lighting and appliances, including water heater (when located in conditioned space), for all equipment located within the conditioned space is sent as internal gains to DOE-2. This value also reflects waste heat from gas appliances located within the conditioned space.

3.1.6 Thermal Distribution Efficiency

As documented in a companion report (Warner 2005), the Home Energy Saver uses the hourly DOE-2 thermal simulation model to estimate heating and cooling consumption. The treatment of air distribution duct losses in DOE-2 is very simple, allowing only a single value of duct losses (expressed as a percent of air input to the ducts) that applies to every hour throughout the year.

Although it would be desirable to model duct efficiency as varying throughout the year, as a function of the ducts' environmental conditions, this would require a significant effort in modifying DOE-2.

Instead, we use an annual-average method for estimating the effect of duct materials and the type of space in which the majority of their duct system is located, since duct losses differ significantly depending on these factors. We used the ASHRAE 152P duct model to estimate duct losses for use as an input to DOE-2 (ASHRAE 1997a). Although this model is intended to calculate seasonal duct efficiencies based on detailed diagnostic testing, we assumed typical values for most of the inputs (such as duct surface area and number of return ducts) so that the number of inputs required of the user is more reasonable.

Users are able to specify whether or not the ducts are insulated and/or sealed, and the duct location. Insulated ducts are assumed to have R-5 insulation, while uninsulated ducts are assigned an insulation value of R-1 (to account for the thermal resistance of the external air film on the ducts). Unsealed ducts are assumed to have a leakage of 30% of the total air handler flow, based on field testing in existing California homes (Jump et al. 1996). Because concerted duct sealing efforts can typically reduce leakage by one-half, we assume that sealed ducts have a leakage rate of 15%. If users choose not to specify their duct location, we infer the location based on the type of foundation and typical building practices. Table 8 shows the default duct location that corresponds to each of the foundation types available in HES.

Table 8. Default Duct Location

Foundation Type	Assumed Duct Location
Unconditioned Basement	Unconditioned Basement
Conditioned Basement	Conditioned Space
Ventilated Crawlspace	Ventilated Crawlspace
Unventilated Crawlspace	Unconditioned Basement
Slab-on-grade	Unconditioned Attic

To account for the effect of local climate on ducts located in unconditioned spaces, the ASHRAE 152P model uses design-day weather data from the ASHRAE Handbook of Fundamentals (ASHRAE 1997b). The model inputs are the winter 97.5% design dry-bulb and the summer 2.5% design dry-bulb, shown in Table C-1.

The ASHRAE 152P model generates seasonal duct efficiencies for both the heating and cooling seasons, which are then averaged together using weights corresponding to the HDD and CDD in that location, normalized to the national average degree-days (using TMY2 data). These weighting factors are shown in Appendix C-1, in the “duct factor” columns. A single annual average duct efficiency is passed to the DOE-2 model as an input to the hourly thermal simulation. This annual duct efficiency is determined based on the type of heating and cooling equipment in the house. The logic for determining the annual duct efficiency is captured in Table

2 by the intersection of heating columns and cooling rows based on the presence or absence of ducts for each type of equipment.

Table 9. Annual Duct Efficiency based on HVAC equipment

Cooling Equipment	Heating Equipment	Duct Efficiency
Doesn't Have Ducts	Doesn't Have Ducts	100% (no duct losses)
Doesn't Have Ducts	Has Ducts	HSE
Has Ducts	Doesn't Have Ducts	CSE
Has Ducts	Has Ducts	$efficiency_{ducts} = DF * HSE + (1 - DF) * CSE$

Notes:

DF = Weight factor based on relative proportions of heating- and cooling-degree days for location
HSE = Weighted heating seasonal duct efficiency from ASHRAE 152P model
CSE = Weighted cooling season duct efficiency from ASHRAE 152P model

3.1.6.1 Boiler Pipe Efficiency

Boiler pipes are assumed to have a baseline efficiency of 90% (Wenzel 1997). Users are able to indicate whether their pipes are insulated. For insulated pipes we stipulate a 5% increase in efficiency.

3.1.7 Infiltration

Air infiltration can be a significant component of thermal losses in residential buildings. In the Home Energy Saver, we calculate the energy impact of air infiltration in the DOE-2 simulation model, based on the leakage area of the thermal shell and location-specific weather data. Although leakage area can be measured using diagnostic testing, few homeowners know the leakage area of their home. To compensate for this lack of information, we estimate leakage area using a database of measured leakage values compiled by LBNL. This database has been analyzed to provide average leakage values for single-family homes based on a few key parameters that strongly influence air leakage (Sherman and Matson 1997, Matson 1998). The LBNL leakage database reports leakage values as Normalized Leakage (NL), or square feet of leakage area per 1000 square feet of conditioned floor area. For input to DOE-2, we converted these normalized leakage values to fractional leakage areas (FLA) using equation 3.

$$FLA = \frac{NL/1000}{\left(\frac{8 \times 0.3048 \times stories}{2.5}\right)^{0.3}}$$

Equation 3

where
FLA = Fractional leakage area, the ratio of envelope leakage area to floor area (square feet/square feet)
NL = Normalized leakage (sq. ft. leakage/sq. ft. conditioned floor area)
stories = 1 if single-story house, otherwise stories = 2
8 = Assumed ceiling height (feet) for the house
0.3048 = conversion factor feet to meters
Source: Sherman, et. al. 1997

The key parameters used to select a house's leakage value from the database are: house vintage (pre-1980, 1980 and later), stories (1, more than 1), shell condition (whether or not air leaks have been sealed in a comprehensive way), presence of a ducted heating or cooling system, and air leakage through the floor (slab or conditioned basement, vs. other foundation types). In addition, for houses built in 1990 or later, we assume a leakage value that is consistent with the "tight" thermal shells typically seen in new construction (NL = 0.5).

3.1.8 Combined Boilers

For houses where the main heating equipment also provides the hot water, the DOE-2 simulation engine calculates the hot water energy consumption. There are two different types of combined boiler, direct and indirect. Direct combined boilers heat the water upon demand. Indirect combined boilers have a storage tank, similar to a stand-alone hot water heater, which provides hot water upon demand. The boiler maintains a steady temperature within the hot water storage tank.

3.1.9 DOE-2 Post-processing

When the DOE-2.1E simulation program executes, it produces a large text output file containing a series of user-specified output reports. We then post-process the raw DOE-2 output file to extract only those results that will be presented to the HES user. These results are drawn from the BEPS, SV-A, SS-A, and PV-A standard reports offered by DOE-2 (Winkelmann, et. al. 1993). Table 10 shows which values are drawn from these reports. The post-processor is implemented in the Perl scripting language.

Table 10. DOE-2.1E Output Reports used in HES

DOE-2 report	Values used in reporting to user	Units
BEPS	Space heat (all fuels) Space cool Pumps & miscellaneous Supplemental heat (heat pump strip heat) Vent fans	Mbtu
SV-A	Heating equipment capacity Cooling equipment capacity	kBtu/hour
SS-A	Annual heating load Annual cooling load Peak heating load Peak cooling load	Mbtu Mbtu kBtu/hour kBtu/hour
PV-A	Boiler capacity	KBtu/hour

3.2 Water Heater Energy Consumption

Two main types of water heaters are modeled in the Home Energy Saver, separate "stand-alone" units, and cases where the home's heating system (boiler) provides the domestic hot water supply. When the hot water is supplied by from a boiler, water heating energy is calculated in the DOE-2 building simulation model. All other water heaters are modeled according to the methodology outlined in this section of the report. For homes with a clothes washer and/or dishwasher, the required gallons of hot water per day is provided as an input to the hot water model (described below) by the clothes washer and dishwasher models.

This module calculates energy consumption for heating water in three steps[5]. The first step is to estimate average daily hot water use. This calculation is based on number and ages of people living in the house, presence or absence of a dishwasher and a clothes washer, the water heater temperature setting and tank size, and the local climate (Lutz, et al, 1996).

Once the average daily hot water use has been estimated, a simple calculation is performed to determine the daily energy use by the water heater. The calculation uses the energy consumption characteristics of the water heater as determined by the DOE Energy Factor test, ambient air and inlet water temperatures, and how much hot water is used on an average day. The last step is to convert the daily energy use into annual consumption of specific fuels.

3.2.1 Daily Hot Water Use

The Home Energy Saver web site uses the following equation[6] to estimate average daily hot water use in gallons per day (Lutz, et al. 1996). This equation was modified and improved from Lutz et al's version by subtracting out the constant assumed hot water use of clothes washers and dishwashers (the variables *cloth* and *dish* in Equation 4), and adding two variables (*cwGals* and *dwGals*) that allow users to individually specify their clothes washer and dishwasher hot water use (e.g. specifying loads washed at certain temperatures). These two variables (*cwGals* and *dwGals*) are used to allocate the water heater energy consumption into three portions; clothes washer, dishwasher and other. The energy consumed by the water heater for the clothes washer and dishwasher portions is reported with the Major Appliance energy in the final report. The calculation of hot water use by clothes washers and dishwashers is described elsewhere in this report.

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[5] Methodology for water heating provided by combined space and water heating systems is described in the companion report (Warner 2005).

[6] The original development of the water heating analytical method was sponsored by the U.S. Department of Energy, Office of Building Technology, State, and Community Programs as part of their appliance standards analysis program (US DOE 2000c).

$$Use_{wh} = \begin{bmatrix} \text{-}1.78 + 0.9744 \times occupants + 6.3933 \times age1 \\ +10.5178 \times age2 + 15.3052 \times (age3 + age4) \\ \text{-}0.1277 \times T_{tank} + 0.1437 \times tank\_size \\ \text{-}0.1794 \times T_{in} + 0.5115 \times average\_temp \\ +10.2191 \times adult\_at\_home - dish - cloth \\ + cwGals + dwGals \end{bmatrix} \times senior \times pay \qquad \textbf{Equation 4}$$

where

Use_{wh} = hot water consumption (gallons/day)
occupants = number of persons in household (sum age1-4)
age1 = number of people aged 0-5 yrs
age2 = number of people aged 6-13 yrs
age3 = number of people aged 14-64 yrs
age4 = number of people aged 65- yrs
T_{tank}= water heater thermostat setpoint (°F)
tank_size = rated volume of water heater (gallons)
T_{in} = inlet water temperature (°F)
average_temp = average annual outdoor air temperature (°F)
adult_at_home = 1 if TRUE, 0 if FALSE, adult at home during day
dish = dishwasher hot water use embedded in original Lutz et al. equation (Lutz, et al. 1996, Equation 12)
cloth = clothes washer hot water use embedded in original Lutz et al. equation (Lutz, et al. 1996, Equation 8)
cwGals = calculated gallons of hot water used by clothes washer based on user inputs, see Section 3.3.3 [replaces more generic estimation method (cloth)] (gallons/day)
dwGals = calculated gallons of hot water used by dishwasher based on user inputs, see Section 3.3.4 [replaces more generic estimation method (dish)] (gallons/day)
pay = 1.3625 if residents do not pay for energy to make hot water (to reflect less water-conserving behavior), otherwise pay = 1
senior = 0.379 if only seniors live in household and it is a multifamily residence, otherwise senior = 1

3.2.2 Daily Water Heater Energy Use

To estimate average daily hot water thermal-energy consumption, we use the following equation (Lutz, et al., 1996). T_{in} is calculated based on the weather data for the weather station to which the house was assigned, described more fully in Section 3.1.1 Climate Modeling.

$$Q_{in} = \frac{use_{wh} \times dens \times Cp \times (T_{tank} - T_{in})}{RE} \times \left[1 - \frac{UA \times (T_{tank} - T_{amb})}{Pon}\right] + 24 \times UA \times (T_{tank} - T_{tamb}) \qquad \textbf{Equation 5}$$

where

Q_{in} = water heating energy consumption (MBtu/day)

use_{wh} = hot water use per day (gallons) from Equation 4
dens = density of water (8.293752 lb/gal)
Cp = specific heat of water (1.000743 Btu/lb-°F)
T_{tank}= water heater thermostat setpoint (°F)
T_{in} = inlet water temperature (°F)
RE = recovery efficiency of water heater
UA = standby heat loss coefficient of water heater (Btu/hr-°F) from Eq. 6
T_{amb} = annual average air temperature around water heater (°F)
Pon = rated input power of water heater (Btu/hr)

3.2.3 Ambient Air Temperature

The average annual air temperature around the water heater (T_{am}) is derived from the location of the water heater. If the water heater is located inside conditioned space, T_{am} is set to the indoor air temperature (default value of 67.5 °F). A future improvement of the modeling would be to have this default indoor air temperature correspond to thermostat settings. If the water heater is located in the basement, T_{am} is set to the average of the indoor and outdoor air temperatures (outdoor air temperature taken from the 30-year-average weather tape data for their location, see Section 4.1 Weather Data), otherwise T_{am} is set to the average outdoor air temperature.

3.2.4 Standby Heat Loss Coefficient

To calculate the standby heat loss coefficient, we use the equation for heat loss from the DOE Energy Factor test procedure for water heaters, (US DOE 1993) as shown in Equation 6.

$$UA = \frac{\frac{1}{EF} - \frac{1}{RE}}{67.5 \times \left(\frac{24}{Q_{out}} - \frac{1}{RE \times Pon} \right)}$$ **Equation 6**

where

UA = standby heat loss coefficient (Btu/hr-°F)
EF = Energy factor of water heater
RE = recovery efficiency of water heater
Pon = rated input power of water heater (Btu/hr)
Q_{out} = Energy content of water drawn from water heater during 24 hour test (41093.7 Btu/day)

3.2.5 Annual Water Heater Energy Use

To estimate average annual hot water energy consumption by type of fuel, we use the following equation.

$$EC_f = 365 \times \frac{Q_{in}}{FC}$$ **Equation 7**

where
EC_f = annual energy consumption for fuel f
Qin = daily water heater thermal-energy use

FC = heat content for fuel f, from Table 3
365 = number of days per year

3.2.6 User Inputs to the Water Heater Model

At the simple inputs level of the Home Energy Saver, users are asked to select the fuel of their water heater. The water heater characteristics (tank size, year purchased, etc.) are defaulted based on choice of water heater fuel (Table XX). The values for recovery efficiency and rated input for the water heater are derived from manufacturers' product specifications (GAMA 1996) for typical models of each fuel type. Tank size was taken from Table 4.4 of the *Energy Data Sourcebook* (Wenzel 1997).

Table 11. Default Water Heater Characteristics by Fuel

Water Heater Fuel	Year Purchased	Recovery Efficiency (%)	Rated Input Value	Rated Input Units	Tank Size (gal)
Electricity	1986	0.98	4.5	kWh/hr	50
Natural Gas	1986	0.76	38,000	Btu/hr	40
LPG	1986	0.76	38,000	Btu/hr	40
Fuel Oil	1986	0.76	0.65	gal/hr	32

3.2.7 Water Heater Energy Factor

The energy factor for the water heater is a derived shipment-weighted efficiency based on the year the equipment was purchased (Table 12). This number is the average efficiency for all units sold within a particular year weighted by the number of units in each efficiency bin (GAMA 1996). For LPG-fired water heaters, we assumed the same energy factor as for natural gas-fire units. For fuel oil-fired units, we assumed an energy factor of 0.54 before 1990 and 0.59 after 1990 (Lutz, personal communication).

Table 12. Shipment Weighted Energy Factors for Water Heaters

Year	Electric	Natural Gas	LPG	Fuel Oil
1972	0.798	0.474	0.474	0.54
1973	0.798	0.474	0.474	0.54
1974	0.798	0.474	0.474	0.54
1975	0.798	0.474	0.474	0.54
1976	0.799	0.475	0.475	0.54
1977	0.799	0.475	0.475	0.54
1978	0.8	0.476	0.476	0.54
1979	0.801	0.476	0.476	0.54
1980	0.802	0.477	0.477	0.54
1981	0.803	0.478	0.478	0.54
1982	0.804	0.479	0.479	0.54
1983	0.806	0.48	0.48	0.54
1984	0.809	0.481	0.481	0.54
1985	0.812	0.483	0.483	0.54
1986	0.815	0.484	0.484	0.54
1987	0.819	0.486	0.486	0.54
1988	0.823	0.488	0.488	0.54
1989	0.828	0.49	0.49	0.54
1990	0.832	0.492	0.492	0.59
1991	0.837	0.494	0.494	0.59
1992	0.842	0.496	0.496	0.59
1993	0.846	0.498	0.498	0.59
1994	0.85	0.499	0.499	0.59
1995	0.854	0.5	0.5	0.59
1996	0.857	0.501	0.501	0.59
1997	0.857	0.501	0.501	0.59
1998	0.857	0.501	0.501	0.59
1999	0.857	0.501	0.501	0.59
2000	0.857	0.501	0.501	0.59
2001	0.857	0.501	0.501	0.59
2002	0.857	0.501	0.501	0.59
2003	0.857	0.501	0.501	0.59
2004	0.9	0.55	0.55	0.59
2005	0.9	0.55	0.55	0.59

Energy Factor for Water Heaters is percentage efficiency divided by 100.
Source: GAMA Directory.
Note: yellow cells contain data held constant from previous real data point.
In 2004, a new standard for water heaters went into effect (green cells).

3.2.8 User Inputs for Water Heater Analysis

In the detail screens of the Home Energy Saver, users can modify the water heater characteristics to more closely simulate their equipment and it's usage. Table 13 shows the range of values for the inputs previously mentioned and lists other characteristics (and their range of values) that users can modify.

Table 13. User Inputs for Water Heaters (Detailed Inputs Level)

Variable Name	Range of Possible Values	Default Value	Modeling Treatment
Fuel	Electric Natural Gas Liquid Propane Gas (LPG) Fuel Oil	Varies by region (zip code)	
Type	Separate from heating system	Separate	Water heater energy calculated using process described in this section
	Combined boiler, tankless		Water heating energy calculated by DOE-2
	Combined boiler, storage tank		
Pay for Fuel (No if solar)	Yes No	Yes	
Adult at Home during weekdays	Yes No	No	
Energy Factor	0 – 1.0	See Table 12	
Recovery Efficiency	0 – 1.0	See Table 11	
Rated Input	0 – 99,000 (kWh, Btu/hr)	See Table 11	
Tank Size (gallons)	0 – 500	See Table 11	
Thermostat setting	Low (120 °F) Medium-Low (130 °F) Medium (140 °F) Medium-High (150 °F) High (160 °F)	Medium-Low (130 °F)	
Location	Basement or Crawlspace	Varies by foundation type	T_{amb}=average($T_{indoors}$+$T_{outdoors}$)
	Garage		T_{amb}= $T_{outdoors}$
	Indoors		T_{amb}= $T_{indoors}$; standby losses sent to DOE2 as internal gains
	Outdoors		T_{amb}= $T_{outdoors}$

Note: T_{amb} = annual average air temperature around water heater (°F)
$T_{indoors}$ = 67.5 °F
$T_{outdoors}$ = average outdoor air temperature from weather tape data

3.3 Major Appliances

Refrigerators, freezers, clothes washers, clothes dryers, dishwashers, stoves and ovens are included in the “Major Appliance” category. Using the number and approximate age of major appliances, the model estimates energy consumption, based on historic sales-weighted efficiency data. This section contains the energy estimation methodology for each appliance. The estimated consumption across equipment types is summed to arrive at the “Major Appliance” category totals.

3.3.1 Refrigerator Energy Consumption

Refrigerators can have very different energy consumption depending on the year of manufacture and features that affect energy use such as size, automatic defrost, or side-by-side design. To estimate the energy consumption of these appliances, we use the calculation method described in the *Energy Data Sourcebook* (Wenzel et al. 1997). Due to changes in technology and Federal efficiency standards, refrigerators have become significantly more efficient over time. Because most consumers do not know the Energy Factor of their refrigerator(s), we use a shipment-weighted energy factor based on the year the refrigerator was purchased (Table 14). This number is the average energy factor for all units sold within a particular year weighted by the number of units in each efficiency bin (AHAM 1996). Note that for purposes of this model, all refrigerators are assumed to be combined refrigerator/freezers. We do not distinguish between refrigerator/freezers located in conditioned space vs. those located in unconditioned space (e.g. in the garage).

$$EC = \frac{(365 \times AV)}{EF} \qquad \textbf{Equation 8}$$

where

EC = Annual energy consumption (kWh/year)
AV = Adjusted volume (cubic feet)
EF = Energy Factor (kWh/cubic feet•year)

The refrigerator / freezer adjusted volume is intended to capture in a single parameter the relatively high energy intensity of the refrigerator's frozen food compartment compared to the fresh food compartment. Equation 9 is used to calculate adjusted volume (US DOE 1995), and corresponds to the definition used in specification of federal minimum efficiency standards.

$$AV = size \times \left(frac + (1 - frac) \times 1.63 \right) \qquad \textbf{Equation 9}$$

where

AV = Adjusted volume (cubic feet)
size = "Nominal" refrigerator/freezer volume (cubic feet)
frac = Fraction of refrigerator volume devoted to fresh-food storage ($0 \le frac \le 1$)

For side-by-side refrigerators, a fresh-food fraction of 0.6 is used, while all other configurations use a fraction of 0.66. Note that this model does not account for refrigerator usage factors that might vary among units, such as refrigerator and freezer temperature settings, door opening frequency, food loading rates, and ambient temperatures. While these factors can have a large impact on energy consumption, their effect has not been quantified in a way that could be incorporated into a parametric model such as this.

3.3.1.1 User Inputs to the Refrigerator Model

At the simple inputs level, users can specify the number of refrigerators in their house, from zero to three refrigerators. Each refrigerator specified has default characteristics (appliance type, size and year) assigned depending on whether it is the first, second or third refrigerator in the house (Table 8). In the detailed inputs calculation mode, users can alter these default characteristics.

Table 14. Shipment Weighted Energy Factors for Refrigerators

Year	General	Automatic defrost		Manual Defrost
		Side-by-Side	Top Freezer	
1972	3.84	3.57	3.56	6.69
1973	4.03	3.81	3.81	6.77
1974	4.22	4.05	4.06	6.85
1975	4.41	4.29	4.31	6.93
1976	4.6	4.53	4.56	7.01
1977	4.79	4.77	4.81	7.09
1978	4.96	5.02	4.75	7.18
1979	5.27	5.32	5.21	7.25
1980	5.59	5.62	5.67	7.32
1981	6.09	5.93	6.12	7.39
1982	6.12	6.02	6.3	7.69
1983	6.39	6.1	6.47	7.98
1984	6.57	6.12	6.75	8.19
1985	6.72	6.36	6.89	5.85
1986	6.83	6.49	6.95	6.14
1987	7.45	7.28	7.66	5.45
1988	7.6	7.45	7.83	5.09
1989	7.78	7.68	8.06	4.55
1990	8.15	7.78	8.51	4.84
1991	8.44	8.26	8.91	4.32
1992	8.8	8.69	9.36	3.5
1993	11.13	12.18	11.39	3.89
1994	11.19	12.45	11.37	4.13
1995	11.22	12.41	11.47	3.75
1996	11.22	12.08	11.48	4.21
1997	10.63	11.44	10.88	3.99
1998	10.50	11.30	10.74	3.94
1999	10.40	11.20	10.64	3.90
2000	11.11	11.96	11.37	4.17
2001	13.58	14.62	13.89	5.10
2002	15.17	16.33	15.52	5.69
2003	15.30	16.47	15.65	5.74

Notes on Refrigerator Energy Factors:
1. Energy Factor has units of (kWh/cubic feet_year), where cubic feet is adjusted volume.
2. Source: (AHAM 1996) (AHAM 2003) - AHAM changed the reporting of refrigerator efficiencies after 1996. Annual data is available for the "General" category. Data for the other refrigerator types for years subsequent to 1996 was

derived from the “General” refrigerator efficiency by scaling the efficiency for a particular type of refrigerator proportional to the annual change in efficiencies in the “General” refrigerator category.
3. Data has been held at 2003 levels for subsequent years.

Table 15. User Inputs for Refrigerator Analysis

Variable Name	Range of possible Values	Default Value	unit
Type	General Automatic Defrost, Side-by-Side Automatic Defrost, Top Freezer Manual Defrost	General	
Year	1972-2002	1990 (1st unit) 1983 (2nd unit) 1972 (3rd unit)	year
Size	Small (13-15 cu ft) Medium (16-18 cu ft) Large (19-21 cu ft) Extra-Large (22+ cu ft)	20 (1st unit) 17 (2nd unit) 14 (3rd unit)	cu. feet

1 Users can specify zero to three refrigerators at the "simple inputs" calculation level.
2. For calculating adjusted volume, the mid-range of each size bin is used, with the exception of the “Extra-Large” bin which uses 24 cu. ft as the calculation value.

3.3.2 Freezer Energy Consumption

Freezer energy consumption is driven by many factors such as configuration (e.g. upright freezers versus chest freezers) and technology (automatic vs. manual defrost capability). Additionally, over the years, freezers have increased in size, causing the overall energy consumption to increase. To estimate the energy consumption of these appliances, we use the calculation method described in the *Energy Data Sourcebook* (Wenzel et al. 1997). Because most consumers do not know the Energy Factor of their freezer(s), we use a shipment-weighted energy factor based on the year the freezer was purchased (Table 16). This number is the average energy factor for all units sold within a particular year weighted by the number of units in each efficiency bin (AHAM 1996). Note that for purposes of this model, all freezers are assumed to be stand-alone units (no fresh food compartment).

$$EC = \frac{(365 \times AV)}{EF} \qquad \textbf{Equation 10}$$

where

EC = Annual energy consumption (kWh/year)
AV = Adjusted volume (cubic feet)
EF = Energy Factor (kWh/cubic feet•year)

The adjusted volume is intended to capture in a single parameter the relatively high energy intensity of the freezer's frozen food compartments. Equation 11 is used to calculate adjusted volume (US DOE 1995). This definition corresponds to the volume used in defining federal minimum efficiency standards

$$AV = size \times 1.73 \qquad \textbf{Equation 11}$$

where

AV = Adjusted volume (cubic feet)
Size = "Nominal" freezer volume (cubic feet)

Note that this model does not account for freezer usage factors that might vary between units, such as temperature settings, door opening frequency, food loading rates, and ambient temperatures. While these factors can have a large impact on energy consumption, their effect has not been quantified in a way that could be incorporated into a parametric model such as this.

3.3.2.1 User Inputs to the Freezer Model

In the simple inputs level, users can specify the number of freezers in their house, from zero to two units. Each freezer specified has default characteristics (appliance type, size and year) assigned depending on whether it is the first or second freezer in the house (Table 17). In the detailed inputs level, users can alter these default characteristics.

Table 16. Shipment Weighted Energy Factors for Freezers

Year	General	Upright Design		Chest Freezers
		Automatic Defrost	**Manual Defrost**	
1972	7.29	5.23	7.65	8.78
1973	7.72	5.43	7.93	9.27
1974	8.15	5.63	8.21	9.76
1975	8.58	5.83	8.49	10.25
1976	9.01	6.03	8.76	10.74
1977	9.44	6.23	9.03	11.23
1978	9.92	6.41	9.31	11.74
1979	10.39	6.95	9.84	11.77
1980	10.85	7.49	10.37	11.8
1981	11.13	8.03	10.89	11.82
1982	11.28	8.23	11.38	11.87
1983	11.36	8.43	11.44	11.91
1984	11.6	8.58	11.51	12.31
1985	11.55	9.5	11.56	12.04
1986	12.07	9.44	12.07	12.84
1987	12.93	9.57	12.6	14.41
1988	12.91	9.31	12.61	14.46
1989	13.89	9.47	13.86	15.48
1990	14.19	10.41	14.15	15.67
1991	14.17	10.43	13.95	15.92
1992	13.95	10.38	13.73	15.63
1993	17.38	13.65	17.3	19.43
1994	16.91	13.14	17.02	18.89
1995	16.57	13.16	16.95	18.28
1996	16.56	13.11	17.09	18.18
1997	16.41	12.99	16.94	18.02
1998	16.3	12.90	16.82	17.89
1999	16.16	12.79	16.68	17.74
2000	15.93	12.61	16.44	17.49
2001	17.38	13.76	17.94	19.08
2002	17.83	14.12	18.40	19.57
2003	17.06	13.51	17.61	18.73

Notes on Freezer Energy Factors:
1. Energy Factor has units of (kWh/cubic feet_year), where cubic feet is adjusted volume.
2. Source: (AHAM 1996) (AHAM 2003) - AHAM changed the reporting of freezer efficiencies after 1996. Annual data is available for the "General" category. Data for the other freezer types for years subsequent to 1996 was derived from the "General" freezer efficiency by scaling the efficiency for a particular type of freezer proportional to the annual change in efficiencies in the "General" freezer category.
3. Data has been held at 2003 levels for subsequent years.

Table 17. User Inputs to the Freezer Analysis

Variable Name	Range of possible Values	Default Value	unit
Type	General Upright, Automatic Defrost Upright, Manual Defrost Chest Freezer	General	
Year	1972-2004	1990 (1^{st} unit) 1983 (2^{nd} unit)	year
Size	Small (13-15 cu ft) Medium (16-18 cu ft) Large (19-21 cu ft) Extra-Large (22+ cu ft)	Medium (1^{st} unit) Small (2^{nd} unit)	cu. feet

3.3.3 Clothes Washer Energy Consumption

Although clothes washers consume energy for both mechanical activities and water heating energy, the majority of the energy used is for water heating. Both machine energy and water heating energy are directly dependent upon the number of loads washed. To estimate the energy consumption of these appliances, Equations 12 and 13 use the calculation method described in the Energy Data Sourcebook (Wenzel et al. 1997). Equation 14 calculates the water heating portion of the total clothes washer energy.

$$EC = ME + WE \qquad \textbf{Equation 12}$$

where

EC = Annual energy consumption in utility units
ME = Machine energy (kWh/year)
WE = Water heating energy attributable to clothes washer in utility units (returned from water heater module)

When ME and WE are in different units (e.g. for non-electric water heaters) the energy consumption for the clothes washer is calculated and stored separately for both fuels (e.g. 126 kWh and 23 therms).

3.3.3.1 Calculating Machine Energy

The machine energy is the electrical energy consumed by all the physical processes necessary to run a load of laundry (e.g. agitation, spin cycle), and is calculated using Equation 13.

$$ME = LE \times loads \times 52 \qquad \textbf{Equation 13}$$

where

LE = load energy (kWh/load)
loads = clothes washer loads/week
52 is weeks/year

Machine energy for the average new clothes washer has not changed significantly over time, so is assumed to be 0.27 kWh/load for the purposes of this model (DOE 1990, Page 3-22 table 3.17).

3.3.3.2 Calculating Water Heating Energy from Clothes Washer Use

The gallons of hot water used by the clothes washer is sent to the water heating model, which calculates the energy consumed by the water heater to supply this amount of hot water to the clothes washer. The daily usage (gallons) attributable to the clothes washer is calculated according to Equation 14 (Koomey et al. 1994).

$$use_{day} = \frac{(loads_{week} * use_{load})}{7} \qquad \textbf{Equation 14}$$

where

Use_{day} = hot water use (gallons/day),
$Loads_{week}$ = number of loads per week,
Use_{load} = hot water use for the average load (gallons/load)
7 = days per week

Energy consumed by the water heater in providing the necessary gallons of hot water for the clothes washer is calculated by the water heating model (see Section 3.2) and incorporated into Equation 12 to arrive at the total energy consumption for the clothes washer.

3.3.3.3 User Inputs to the Clothes Washer Model

At the simple inputs level in the Home Energy Saver, users only indicate whether or not a clothes washer is present in their house. A default value for the clothes washer contribution to gallons of hot water per day is set for those houses with clothes washer.

For the detailed inputs level, the number of clothes washer loads is assumed to be 380 loads/year (US DOE 1990) and gallons of hot water per load depends on the temperature setting for the load (Lutz et al. 1996). The default distribution of clothes washer temperature settings was based on our judgment about typical usage patterns. Users can customize the number of loads washed and the temperature settings to match the usage patterns in their house.

Table 18. Default values for calculating clothes washer gallons

	Use_{day} (gallons/day)	# of $Loads_{week}$	Temperature (wash/rinse)	Use_{load} (gallons)	Source
Simple Level	8.2	-	-	-	(Koomey et al. 1994) Table 4
Detailed Inputs Level	9.1	2	Hot/Warm	32	(Lutz et al. 1996) Table 1
	0.0	0	Hot/Cold	20	“
	9.4	3	Warm/Warm	22	“
	2.9	2	Warm/Cold	10	“
total	21.4	7			“

3.3.4 Clothes Dryer Energy Consumption

Clothes dryers consume energy for both mechanical activities and the drying process. The majority of the energy used is for drying. Both machine energy and drying energy are directly dependent upon the number of loads dried. To estimate the energy consumption of these appliances, Equations 15 and 16 use the calculation method described by Wenzel et al. (1997).

$$EC_f = ME + DE \qquad \textbf{Equation 15}$$

where

EC_f = Annual energy consumption for fuel f
ME = Machine energy (kWh/year)
DE = Drying energy in utility units (kWh/year or therms/year)

Energy consumption is portrayed in "utility units" for each fuel type; the electric utility is kWh, natural gas utility unit is therms,

3.3.4.1 Machine Energy

The machine energy includes the energy consumed by all the mechanical and electrical processes necessary to dry a load of laundry (e.g. drum rotation, timers etc.). Equation 16 is used to calculate the machine energy.

$$ME = LE \times loads_{week} \times 52 \qquad \textbf{Equation 16}$$

where

LE = load energy (kWh)
$loads_{week}$ = clothes dryer loads/week
52 = weeks/year

Machine energy for the average new clothes dryer has not changed significantly over time, so is assumed to be 0.23 kWh/load for the purposes of this model (PG&E 1995).

3.3.4.2 Drying Energy

The energy consumed by the clothes dryer to produce heat necessary to dry the clothing is called the drying energy. The drying energy is calculated according to Equation 17.

$$DE = loads_{week} \times use_{load} \times 52 \qquad \textbf{Equation 17}$$

where

$Loads_{week}$ = number of loads per week,
Use_{load} = drying energy consumption per load (kWh or therms)
52 = weeks per year

The Home Energy Saver models electric and gas clothes dryers. Electric clothes dryers use 3.8 kWh and gas clothes dryers use 0.22 therms per load (PG&E 1995) for drying energy alone. This energy consumption is in addition to the electricity required to operate the mechanical functions of clothes drying (air circulation, drum rotation, timers and sensors, etc.) Our calculation process does not distinguish between models that have moisture-sensor termination and those that do not.

3.3.4.3 User Inputs to the Clothes Dryer Model

The method of estimating clothes dryer energy depends on the user inputs available for each of the different levels of user inputs. At the simple inputs level in the Home Energy Saver, no user inputs are available concerning the clothes dryer. An electric clothes dryer is assigned to the house as the default if users indicate that they have a clothes washer. The number of loads dried is assumed to be equal to the number of loads of laundry washed.

For the detailed inputs level of the Home Energy Saver, the initial number of clothes dryer loads is assumed to be 380 loads/year (US DOE 1990). Users can customize the number of loads dried and select the primary fuel used for providing heat.

3.3.5 Dishwasher Energy Consumption

Dishwashers consume energy for both mechanical functions and water heating, with the majority of the energy used for water heating. Both machine energy and water heating energy are directly dependent upon the number of loads washed. To estimate the energy consumption of these appliances, Equations 18 and 19 use the calculation method described by Wenzel et al. (1997).

$$EC = ME + WE \qquad \textbf{Equation 18}$$

where

EC = Annual energy consumption in utility units
ME = Machine energy (kWh/year)
WE = Water heating energy in utility units (returned from water heater)

When ME and WE are in different units (e.g. for non-electric water heaters) the energy consumption is reported and tracked in terms of more than one fuel (e.g. 126 kWh and 23 therms).

3.3.5.1 Machine Energy

The machine energy (Equation 19) includes the energy consumed by all the physical processes necessary to run a load of dishes (e.g. pumps, heating element for drying cycle).

$$ME = LE \times loads \times 52 \qquad \textbf{Equation 19}$$

where

LE = load energy (kWh/load)
loads = dishwasher loads/week
52 = weeks/year

Machine energy for dishwashers is assumed to be 0.78 kWh/load for the purposes of this model (US DOE 1990, Page 3-8 table 3.4).

3.3.5.2 Water Heating Energy

The quantity of hot water used by the dishwasher is sent to the water heating model, which calculates the energy consumed to supply this amount of hot water to the dishwasher. The daily hot water usage (gallons) attributable to the dishwasher is calculated according to Equation 20 (Koomey et al. 1994).

$$use_{day} = \frac{(loads_{week} * use_{load})}{7} \qquad \textbf{Equation 20}$$

where

Use_{day} = hot water use (gallons/day),
$Loads_{week}$ = number of loads per week,
Use_{load} = hot water user per average load (gallons/load)
7 = days per week

Energy consumed by the water heater in providing the necessary amount of hot water for the dishwasher is calculated by the water heating model (see Section 3.2) and incorporated into Equation 18 to arrive at the total energy consumption for the dishwasher.

3.3.5.3 User Inputs to the Dishwasher Models

At the simple inputs level, users are unable to indicate whether or not a dishwasher is present in their house. A dishwasher is assigned to the house if the user indicates that they own a clothes washer. The default value for the daily gallons of hot water used by the dishwasher is set at the time of dishwasher assignment.

For the detailed inputs level, the number of dishwasher loads is initially defaulted to 208 loads/year (US DOE 1990) with hot water usage of 11 gallons per load (Lutz et al. 1996). Users can indicate the presence of a dishwasher and the number of loads washed per week.

Table 19. Default values for calculating dishwasher gallons

	Use_{day} (gallons/day)	# of $Loads_{week}$	Use_{load} (gallons/load)	Load Energy (kWh/load)
Simple inputs	3.4[a]	-	-	0.78[b]
Detailed inputs	6.3	4[a]	11[c]	0.78[b]

Notes:
[a] (Koomey et al. 1994) Table 4
[b] DOE 1990, page 3-8 Table 3.4
[c] (Lutz, et al. 1996) Table 4

3.3.6 Stove and Oven Energy Consumption

3.3.6.1 Stove Energy Consumption

In the Home Energy Saver, users are allowed to select between electric and gas stoves. Equation 21 describes the method used to calculate energy consumption by electric stoves. Equation 22 is used with gas stoves.

$$EC = power \times usage_{day} \times 365 \qquad \textbf{Equation 21}$$

where

EC = Annual energy consumption in kWh
power = energy consumption rate of stove (kWh/hour)
$usage_{day}$ = hours of use per day for all burners combined
365 = days per year

For electric ranges, the power consumed is assumed to be 1 kW for the purposes of this model (PG&E 1995).

$$EC = (burner\_rate \times usage_{day} \times 365) + pilotLight$$ **Equation 22**

where

EC = Annual energy consumption in therms
burner_rate = energy consumed by stove (therms/hour)
$usage_{day}$ = hours of use per day for all burners combined
365 is days per year
pilotLight = energy consumed by the pilot light (therms/year)

For gas ranges, the rate of energy use is assumed to be 0.09 therms/hour and pilot light consumption is 17 therms/year (PG&E 1995). The default usage is 1 hour per day for both electric and gas ranges.

3.3.6.2 Oven Energy Consumption

In the Home Energy Saver, users are allowed to select either an electric and gas oven. Equation 23 describes the method used to calculate energy consumption by electric ovens. Equation 24 is used for gas ovens.

$$EC = power \times usage_{week} \times 52$$ **Equation 23**

where

EC = Annual energy consumption in kWh
power = energy consumed by oven (kWh/hour)
$usage_{week}$ = hours of use per week for the oven
52 = weeks per year

For electric ovens, the power consumed is assumed to be 2.3 kWh/hour [or 2.3 kW] for the purposes of this model (PG&E 1995). For gas ovens,

$$EC = (oven\_rate \times usage_{week} \times 52) + pilotLight$$ **Equation 24**

where

EC = Annual energy consumption in therms
oven_rate = energy consumed by stove (therms/hour)
$usage_{week}$ = hours of use per week for all burners combined
52 is weeks per year
pilotLight = energy consumed by the pilot light (therms/year)

For gas ovens, the energy consumed is assumed to be 0.11 therms/hour and pilot light consumption is 17 therms/year (PG&E 1995). The default usage for all ovens is assumed to be 2 hours per week, regardless of oven fuel.

3.3.6.3 User Inputs to the Stove and Oven Model

Users are able to alter the inputs for stoves and ovens only in the detailed inputs model. Table 20 details the initial assumptions used for calculating stove and oven energy.

Table 20. User Inputs for Stoves and Ovens

Variable Name	Range of possible Values	Default Value	unit
Stoves			
StoveFuel	Electric Gas	Electric	
Usage	0 – 10 hours	1	Hours/day
Ovens			
OvenFuel	Electric Gas	Electric	
Usage	0 – 10 hours	2	Hours/week

3.4 Miscellaneous Equipment Energy Consumption

3.4.1 General Methodology

The model allows estimation of energy consumption for about seventy-five miscellaneous gas and electric appliances, with default values based on data compiled over the years by LBNL researchers. As with the other modules, default values can be over-ridden by the user to create a more accurate characterization of the type and use of miscellaneous equipment in the home.

The miscellaneous appliance category contains a varied assortment of small and/or unusual devices that could occur in a house, both electricity and gas. They are divided into several main categories; Entertainment, Home Office, Miscellaneous Kitchen Appliances, Hot Tubs and Spas, and Other Appliances. Energy for a particular piece of equipment is calculated according to the following equation and summed across all miscellaneous equipment to get total miscellaneous equipment energy consumption.

$$UEC = \left(\frac{ActivePower + StandbyPower}{1000} \right) \times NumberMachines \qquad \textbf{Equation 25}$$

where

UEC = annual energy consumed by the equipment (kWh)
ActivePower = ((P1 * P1Usage) + (P2 * P2Usage) +... + (Pn * PnUsage))
Pn = the energy consumed at various power levels (e.g. active use, on but idle etc.)
PnUsage = hours per year the equipment spends at this power rate.
StandbyPower = (8760 – Sum(all active Usages)) * StandbyRate
StandbyRate = energy consumed in standby mode
1000 converts WattHours to kWh.
NumberMachines = the quantity of this type of equipment in the house.

Typical energy consumption rates (both Active and Standby rates) for each piece of equipment as well as standard patterns of usage are documented in Table 21. We selected the default set of miscellaneous equipment types present in a house by examining the national saturation for each type. Those devices for which Sanchez (1998) estimated a national saturation greater than 80% were selected as part of the default set for all houses.

At the detailed inputs level, users can add and remove specific miscellaneous equipment types from the default set, and specify the usage for each item. Table 21 lists the equipment types present in the Home Energy Saver, showing the number of instances of this type of equipment included in the default set for all houses, the energy consumption for various modes of activity, both per unit time and annual totals, and the default usage assumption.

Table 21. Default Energy Consumptions and Characteristics for Misc. Equipment

Appliance	Number Present in Default House	Estimated Wattage	Usage Increment	Usage Period	Season Increment (Months/ Year)	Active Usage (hours/ Year)	Active consumption	Standby Wattage	Standby Usage (hour/yr)	Standby consumption	Total kWh
Home Entertainment											
Boom Box	1	8	30	minutes / week		26	0	5.2	8734	45	46
Cable Boxes (standby losses)	1	140	90	minutes / day		548	77	11.6	8213	95	172
CD Player	1	7	30	minutes / week		26	0	3.7	8734	19	19
DVD Player	0	16	4	hours / week		208	3	5.5	8552	14	17
Receiver	1	28	2	hours / week		104	3	2.8	8656	24	27
satellite stations (standby losses)	0	25	2	hours / week		104	3	15	8656	130	132
Tape Player	1	8	2	hours / week		104	1	1.0	8656	9	9
Telephone Answering Machine	1	4.5	24	hours / day		8760	39	2.2	0	0	39
TV (CRT - Projection)	0	225	2	hours / day		730	164	6.4	8030	51	216
TV (CRT)	2	60	2	hours / day		730	44	6.4	8030	51	95
TV (DLP)	0	175	2	hours / day		730	128	6.4	8030	51	179
TV (LCD)	0	150	2	hours / day		730	110	6.4	8030	51	161
TV (Plasma)	0	300	2	hours / day		730	219	6.4	8030	51	270
VCRs	1	18	2	hours / week		104	2	5.3	8656	46	48
Video Games	1	20	1	hour / day		365	7	0	8395	0	7
Home Office											
Computer CPU	1	68	5	hours / day		1825	124	1.2	6935	8	132
home copiers	0	800	30	minutes / day		183	146	5.1	8578	44	190
Home facsimile machines (thermal)	0	175	4	minutes / day		24	4	30	8736	131	135
Home fax/Multi-function device (inkjet)	0	18	4	minutes / day		24	0	8	8736	70	70
Laptop Charger	0	0	0			0	0	4.5	8760	39	39
Monitor	1	84	5	hours / day		1825	153	2.0	6760	14	167
Printers (Inkjet)	1	13	1	hour / week		52	1	4.2	8708	37	37
Printers (Laser)	0	250	1	hour / week		52	13	4.2	8708	37	50
Router/DSL/Cable Modem	1	6	5	hours / day		1825	11	2	6935	14	25

Hot Tub, Pools and Pumps												
Pool Heater	0	275	6	hours / day	4	730	201	0	8030	0	201
Pool Pump	0	2250	6	hours / day	4	730	1643	0	8030	0	1643
Spa (24 hour elec)	0	0	0	hours / day		0	0	263	8760	2300	2300 kWh
Spa (24 hour gas)	0	0	0	hours / day		0	0	12	8760	105	105 therms
Spa (on-demand elec)	0	5500	4	hours / week		208	1144	0	0	0	1144 kWh
Spa (on-demand gas)	0	1.5	4	hours / week		208	0	0	0	0	312 therms
Sump/Sewage Pump	0	1/3 hp	25	hours / year		0	25	0	8760	0	9
Well Pump	0	0	0			0	0	0	8760	0	0
Misc. Kitchen											
Bottled Water Dispenser	0	0	0			0	0	34	8760	300	300
Broilers	0	1400	1	hour / week		52	73	0	8708	0	73
Coffee Maker: Drip (Brew)	1	1500	30	minutes / day		183	274	1	8578	9	282
Coffee Maker: Drip (Warm)	0	70	1	hour / day		365	26	0	8395	0	26
Coffee Maker: Percolater (Brew)	0	600	30	minutes / day		183	110	0	8578	0	110
Coffee Maker: Percolater (Warm)	0	80	1	hour / day		365	29	0	8395	0	29
Compactors	0	400	20	minutes / day		122	49	0	8638	0	49
Deep Fryer	0	1000	23	minutes / week		20	20	0	8740	0	20
Espresso Maker	0	360	1	hour / week		52	19	0	8708	0	19
Fry Pans	0	1000	14	hours / month		162	162	0	8598	0	162
Instant Hot Water	0	0	0			0	0	18	8760	160	160
Microwaves	1	1000	13	minutes / day		79	79	2.8	8681	24	103
Slow Cookers	0	200	13	hours / week		693	139	0	8067	0	139
Toaster	1	1100	6	minutes / day		37	40	0	8724	0	40
Toaster Oven -Toasting	0	460	4	minutes / day		25	12	0	8735	0	12
Toaster Oven - Oven	0	1500	23	minutes / day		140	210	0	8620	0	210
Other Miscellaneous											
Aquariums	0	63	24	hours / day		8760	548	0	0	0	548
Auto Engine Heaters	0	1500	1	hours / day	5	152	228	0	8608	0	228

Clock	2	0	0			0	0	1.0	8760	9	9
Dehumidifiers	0	46	24	hours / day		8760	400	0	0	0	400
Doorbell	1	0	0			0	0	5	8760	44	44
Electric Blankets	0	400	5	hours / day	2	304	122	0	8456	0	122
Electric Grills	0	1800	5	hours / week	5	108	195	0	8652	0	195
Electronic Air Cleaner/Filter	0	50	3	hours / day		1095	55	0	7665	0	55
Garage Door Openers	0	400	8	minutes / day		49	19	2.8	8711	24	44
Gas Grills	0	0.33	5	hours / week	5	108	36	0	8652	0	0
Gas Lighting	0	0.24	6	hours / week	3	78	19	0	8682	0	0
Hair Dryers	1	710	8	minutes / day		49	35	0	8711	0	35
Heat Tape	0	1000	1	hours / day	3	91	91	0	8669	0	91
Humidifier	0	11	24	hours / day		8760	100	0	0	0	100
Irons	0	1100	55	minutes / week		48	53	0	8712	0	53
Pipe and Gutter Heaters	0	500	2	hours / day	3	183	91	0	8578	0	91
Rechargable Handheld Vacuum (charging)	0	0	0			0	0	5	8760	44	44
Vacuum - Canister	0	818	1	hour / week		52	43	0	8708	0	43
Vacuum-Upright	1	297	1	hour / week		52	15	0	8708	0	15
Water Bed Heaters	0	0	0			0	0	102	8760	900	900

Data from Sanchez et al, 1998

Data from Nordman et al. 2004.

Data from Ross, et al. 2000.

Average wattage determined by web search of typical units

Average pump capacity (horsepower) taken from Granger Catalog search of sump pumps.

Data from CCAP spreadsheet (CCAP_040905)

Non colored values calculated from colorcoded source values

3.4.2 Well-pump energy calculation method

To calculate electrical energy for well pumps, we first calculate the energy needed to lift and pressurize the water for delivery to the home, then divide by the overall efficiency of the pump and motor system (Wateright 2003 and Greenberg 2005). The amount of energy required is a function of the amount of water consumed by the household. We estimate annual indoor water consumption using the following equation developed through a water end-use metering study (Mayer et al. 1999).

$$AIC = (37.2 \times occupants + 69.2) \times 365 \qquad \textbf{Equation 26}$$

where:

AIC	= Annual indoor water consumptions (gallons)
Occupants	= total number of household occupants
365	= converts daily to annual consumption

Outdoor water consumption is estimated using data from Mayer et al. (1999).[7] Because outdoor water use depends heavily on house-specific usage patterns (e.g., landscaping or swimming pools), we allow the user to select their outdoor water usage category, shown in Table 22.

Table 22. Outdoor Annual Water Consumption per Household

Outdoor water usage category[a]	Outdoor water consumption (thousand gallons per year)
Roughly 5 min/day	10[b]
Roughly 30 min/day	50[b]
Roughly 45 min/day	84.7[c]
Roughly 1.25 hours/day	150[d]
Roughly 2 hours/day	200[b]
Roughly 2.75 hours/day	300
Roughly 3.5 hours/day	400

Notes:
[a] Watering times assumes a typical garden house with 5 gal/min flow rate.
[b] These values are drawn from Mayer et al., table 5.14. All other values are extrapolations extending the range for use as a user input.
[c] This is the mean value of outdoor water use reported by Mayer et al. (146,100 gallons mean annual household consumption, with 58% of that amount allocated to outdoor uses).
[d] Default value.

$$WP = \frac{TDH \times GPM}{3960} \qquad \textbf{Equation 27}$$

where:

WP	= Annual average water power (hp)
TDH	= Total Dynamic Head (feet)
GPM	= Annual average flow rate of well (gallons per minute)

[7] The Mayer et al. study shows that indoor water use is relatively constant across the country, but outdoor water use can vary by a factor of 20 or more between regions of the country. A possible future improvement to our water use model would be to use the Mayer et al. study to estimate the relationship between climate and outdoor water use.

= Annual water consumption (gallons per year) ÷ 525,600 (min/year)
3960 = Unit conversion constant (feet•gallons/minute to horsepower)

To calculate total dynamic head (TDH), we use the following equation.

$$TDH = WellDepth + AdditionalHeight + pressurizationHead$$ **Equation 28**

where:

AdditionalHeight = Additional Height from well head to house

In practice, dynamic head would be a function of the depth to water and also include a term for friction losses in the piping. To simplify our calculations and make it easier for the user to describe their well system, we calculate dynamic head using the well depth (which will always be greater than the depth to water) and ignore piping friction losses, under the assumption that these two factors approximately cancel each other out. As a default, we assume that the average residential well in the U.S. is 150 feet deep. Because pressurization head (the pressure at which water is delivered to the piping in the house) is normally expressed using units of pressure (rather than feet of head), we convert from pressure to head using a ratio of 2.31 feet of head per psi. We assume 50 psi as a typical pressurization level for residential water systems supplied by wells. Pressurization head is only included if the user indicates that the water pressure in their house is provided by a water pump (versus gravity flow from storage).

$$EP = WP \times 0.746 \times \frac{1}{\eta_s}$$ **Equation 29**

where:

EP = Electrical power (kW)
WP = Water power (hp)
η_s = Overall efficiency of pump and motor system (decimal value, 0 to 1)

The efficiency of pump and motor systems can vary widely depending on the type of pump and motor, well configuration, and maintenance practices. Representative values for efficiency are not published, but it has been suggested that overall efficiencies between 0.15 and 0.60 are typical. For modeling in HES, we assume a combined efficiency of 0.40 for residential well pump/motor systems. For modeling best available pump/motor systems, we assume a combined efficiency of 0.60.

Finally, we calculate annual energy consumption for well pumping using the following equation:

$$PumpingEnergy = EP \times 8760$$ **Equation 30**

where:

8760 = hours per year

3.5 Lighting Energy Consumption

Accurately estimating the energy consumption of lighting requires detailed information about the technical specification of the fixture and the typical usage pattern for that fixture. Since not all consumers are willing or able to provide that level of detail, the Home Energy Saver offers a means to arrive at lighting consumption with minimal user input as well as a more complete calculation model. Lighting fixtures are grouped according to the room in which they are located. Equation 31 calculates the lighting energy consumption for all fixtures in a room. Lighting consumption at the household level is simply the sum of energy consumed by all rooms.

$$EC = \sum_{i=1}^{n} FE_i \qquad \textbf{Equation 31}$$

where

EC = Annual lighting energy consumption by room (kWh/year)
FE = Fixture energy (kWh/year)
n = number of fixtures in room

The fixture energy represents the energy consumption of both the lamp and ballast components of a light fixture. A fixture consists of all the lamps controlled on a single circuit. Fixture energy is calculated using Equation 32.

$$FE = \left(\frac{P_{lamp} + P_{ballast}}{1000} \right) * usage * 365 \qquad \textbf{Equation 31}$$

where

P_{lamp} = combined power for all lamps in fixture (Watts)
$P_{ballast}$ = total ballast power for fluorescent fixtures (Watts)
usage = fixture usage (hours/day)
365 is days per year

Note that ballast energy is only applicable for fluorescent tube fixtures. Any ballast energy for compact fluorescent fixtures and halogen fixtures is included in the total lamp wattage for the fixture, entered by the user. Ballast fixture power is given by

$$P_{ballast} = 130 * \left(\frac{NL}{2} \right) \qquad \textbf{Equation 33}$$

where

130 = Ballast power (Watts)
NL = number of lamps in fixture
[Note (NL/2) is rounded to next-higher integer value]

3.5.1 User Inputs to the Lighting Model

At the simple inputs level of modeling, users are asked to specify the number of fixtures per room. The model then estimates the energy consumption per room, using default values based on the appropriate room (Table 22), derived from a Tacoma Public Utilities Study (Jennings et al. 1997; Tribwell and Lerman 1996). Where these default data are used, all fixtures in the room are considered to be identical. Alternatively, at the detailed inputs level of modeling, users are able to enter lamp type, number of lamps/fixture, total fixture wattage and usage individually for every fixture.

Table 23. Default Lighting Fixture Parameters

Room	Lamp Type	# of Lamps / Fixture	Ave. Lamp Power (W)	Ave. Fixture Power (W)	Usage (hr/day)	Annual UEC by Room (kWh)
Kitchen	Incandescent	2	59	95	3	218
Dining Room	Incandescent	3	62	165	2	136
Living Room	Incandescent	1	98	124	2	109
Family Room	Incandescent	1	73	106	2	77
Master Bedroom	Incandescent	1	68	93	1	81
Bedroom	Incandescent	1	68	94	1	73
Closet	Incandescent	1	60	66	1	0
Bath	Incandescent	2	70	138	2	192
Hall	Incandescent	1	65	78	2	98
Utility	Incandescent	1	62	84	2	0
Garage	Incandescent	1	75	103	2	71
Outdoor	Incandescent	1	84	110	3	231
Other	Incandescent	1	72	103	1	0

Notes:
1) Number of lamps derived from average Lamp and Fixture power.
2) Available lamp types are Incandescent, Halogen Torchiere, Compact Fluorescent and Fluorescent tubes
3) Allowable usage is from 0 to 24 hours/day

4. Default Energy Consumption and House Configuration

4.1 Average Energy Bills for Existing Houses

In order to provide users an initial estimate of energy savings potential in their house, we estimated average energy bills by climate region from the sample of single-family housing units (including manufactured homes) in the 1993 and 2001 RECS microdata (US DOE 1995a, US DOE 2004). Users see this information immediately following entry of the zip code.

Energy bills by end-use are based on the end-use consumption estimates reported in the RECS microdata. For each housing unit in the RECS sample, EIA reports the Census Division in which that housing unit is located, as well as summary climate data (HDD and CDD) from the geographically closest weather station.

In order to provide finer geographic disaggregation of the RECS data, we assign each of the RECS housing units to one of 19 climate regions in the U.S. These climate regions were originally developed by LBNL in a project for the Gas Research Institute (Ritschard et al. 1992) and extended by Huang (Huang et al. 1999) and Apte (Apte 2004). The 19 climate zones are described in Table 24. Using these climate-region assignments, within each climate region we select those single-family housing units that have the most common heating and cooling characteristics (heating fuel, water heating fuel, and presence of central air conditioner) for that region.

The energy consumption for space heating, space cooling and water heating was determined from this subset of housing units. Energy consumption for appliances was derived from the full set of single-family housing units for each climate zone. The 2001 Residential Energy Consumption Survey has not included data on lighting consumption since 1993, so the lighting energy consumptions was taken from the 1993 RECS microdata (US DOE 1995a). The final consumption values are shown in Appendix B, Default Energy Consumption

Table 24. Climate Zone Assignment

Division	Heating/Cooling Days	Climate Zone
New England	any	1
Mid-Atlantic	any	2
East No. Central	any	3
(No zone four)		
West No. Central	HDD65 > 7000	5
West No. Central	HDD65 < 7000	6
So. Atlantic	HDD65 >= 4000	7
So. Atlantic	HDD65 < 4000 and CDD65 < 3000	8
So. Atlantic	HDD65 < 4000 and CDD65 > 3000	9
East So. Central	HDD65 >= 4000	10
East So. Central	HDD65 < 4000	11
West So. Central	HDD65 >= 2000	12
West So. Central	HDD65 < 2000	13
Mountain	HDD65 >= 7000	14
Mountain	5000 < HDD65 < 7000	15
Mountain	HDD65 < 5000 and CDD65 < 2000	16
Mountain	HDD65 < 5000 and CDD65 > 2000	17
Pacific	HDD65 > 4000	18
Pacific	2000 < HDD65 < 4000	19
Pacific	HDD65 < 2000	20

The climate zone assignment is determined by the Census division and heating and cooling degree days (see Table 24) which are directly taken from the RECS micodata set. We determine the most common characteristics through the default house analysis described in section 3.1.2. These characteristics, and the number of RECS records meeting those criteria, are shown in Table 25. We select only the houses that had the most common characteristics because we want their average energy use to correspond to the default house characteristics for that region (to provide internal consistency within the HES model).

The default energy consumption values from the RECS survey and the calculated energy consumption values returned from the DOE 2.1E building simulation model are converted from Mbtu to utility units (kWh, therm, etc.) for presentation to the user, using the following equations.

Electricity:

$$Energy_{kWh} = Energy_{Mbtu} * \ 1{,}000{,}000 \ / \ 3412 \qquad \textbf{Equation 33}$$

Natural Gas:

$$Energy_{therm} = Energy_{Mbtu} * \ 10 \qquad \textbf{Equation 34}$$

Fuel Oil (gallon of fuel oil):

$$Energy_{gallon} = Energy_{Mbtu} * \ 1{,}000{,}000 \ /138{,}690 \qquad \textbf{Equation 35}$$

Liquid Propane Gas (gallon):

$$Energy_{gallon} = Energy_{Mbtu} * \ 1{,}000{,}000 \ /85{,}786 \qquad \textbf{Equation 36}$$

Table 25. Typical Heating and Cooling Characteristics for each Climate Zone

Climate Zone	Heating Fuel	Water Heating Fuel	Central Cooling?	Number of Housing Units
1	Fuel Oil	Fuel Oil	No	3656165
2	Natural Gas	Natural Gas	Yes	9005530
3	Natural Gas	Natural Gas	Yes	13267528
5	Natural Gas	Natural Gas	Yes	1975960
6	Natural Gas	Natural Gas	Yes	4258550
7	Natural Gas	Natural Gas	Yes	3693237
8	Electricity	Electricity	Yes	9473774
9	Electricity	Electricity	Yes	3151667
10	Electricity	Electricity	Yes	1080956
11	Natural Gas	Natural Gas	Yes	4855664
12	Natural Gas	Natural Gas	Yes	5026693
13	Natural Gas	Natural Gas	Yes	4584481
14	Natural Gas	Natural Gas	No	1011371
15	Natural Gas	Natural Gas	No	2244047
16	Natural Gas	Natural Gas	No	434697
17	Natural Gas	Natural Gas	No	1700087
18	Natural Gas	Natural Gas	No	3267745
19	Natural Gas	Natural Gas	No	2998674
20	Natural Gas	Natural Gas	No	4809105

4.2 Bill Savings in Typical Houses due to Energy Efficiency Upgrades

In order to provide users an idea of how much they could potentially save on their energy bills, we have estimated technical savings potentials for typical houses in U.S. regions. These estimates of savings potential are applied to the average existing energy bills by climate region, as described in the previous section. Users see this information immediately following entry of their zip code.

To estimate the potential savings, we select a single house from the 1990 RECS sample to represent each census division. These houses are selected such that their utility bills are within 10% of the median value in each census division, and they have the heating and cooling equipment most common in that census division. These selected houses are single-family detached, with floor area ranging from 1100 to 2900 square feet. 1990 RECS utility bill data are inflated to 1995 dollars using the Consumer Price Indices for electricity, piped gas, and fuel oil. The characteristics of the selected houses are shown in Table 26.

We then estimate the utility bills for these houses, assuming that "best available" technology were applied to the building shell and the equipment contained in that house (according to the RECS survey). Best available technology is generally defined as the most efficient products on the market. The savings estimates are based on several sources, including an LBL supply curves analysis (Koomey et al. 1991) and unpublished updates to that analysis; the U.S. DOE Water Heater standards analysis (U.S. DOE 2000c); a U.S. EPA analysis of space conditioning efficiency improvements (L'Ecuyer et al. 1993); the Honeywell Thermostat Energy Savings Estimator program (Honeywell 1994); Mark Modera (1998); and model directories from the Air conditioning and Refrigeration Institute (ARI 1995), Gas Appliance Manufacturers Association (GAMA 1996), and the California Energy Commission (CEC 1998). The resulting savings factors are shown in Table 27. For lighting, we assume 50% savings are achievable with a combination of compact fluorescent lamps and outdoor lighting controls.

4.3 Carbon Emissions in Typical Houses

To estimate CO2 emissions for the default house consumption (Typical House), we use regional emission factors for electricity, and national emission factors for fuel-fired appliances and equipment. For electricity, we developed regional emissions factors using total emissions for fossil steam generation units (US DOE 1996), divided by net generation in each census division.[8] We then added 8% transmission and distribution losses. Finally, we scaled up to account for the additional generation (roughly 2% nationally, but different regionally) that is associated with combustion turbines and internal combustion engines. This approach assumes that the combustion turbines and IC engines have, on average, the same emissions per kWh as the other fossil-steam plants. The resulting values are annual averages for all electricity generated within that region. The resulting emission factors are shown in Table 28.

[8] This methodology accounts for zero-emission generation from hydro, nuclear, and renewables.

Table 26. Estimated Utility Bills After Switching to ENERGY STAR or Best Available Technology

Census Division	City	Heat Fuel	CAC	# RAC	1995 $ Water Heat Fuel	Total Utility Bill	Baseline Bill ($1995/year) Space Heat	Space Cool	Water Heat	Appl-iances	Total Bill
New England	Worcester, MA	fuel oil	no	1	fuel oil	$1,621	$728	$24	$162	$707	$1,621
Mid Atlantic	Philadelphia, PA	natural gas	no	2	natural gas	$1,891	$695	$201	$212	$784	$1,891
East North Central	Springfield, IL	natural gas	no	0	natural gas	$1,783	$686	$0	$302	$794	$1,783
West North Central	Minneapolis, MN	natural gas	yes	0	natural gas	$1,023	$463	$73	$127	$360	$1,023
South Atlantic	Charleston, SC	electricity	yes	0	electricity	$1,073	$134	$391	$121	$427	$1,073
East South Central	Nashville, TN	electricity	yes	0	electricity	$1,266	$316	$234	$238	$478	$1,266
West South Central	Dallas, TX	natural gas	yes	0	natural gas	$1,312	$297	$454	$113	$448	$1,312
Mountain North	Denver, CO	natural gas	no	0	natural gas	$1,301	$459	$0	$142	$700	$1,301
Mountain South	Phoenix, AZ	electricity	yes	1	electricity	$1,054	$109	$334	$152	$458	$1,054
Pacific North	Seattle, WA	electricity	no	0	electricity	$998	$577	$0	$97	$323	$998
Pacific South	Los Angeles, CA	natural gas	yes	0	natural gas	$1,058	$130	$305	$59	$564	$1,058

Table 27. Estimated Utility Bill Savings After Switching to ENERGY STAR or Best Available Technology

Census Division	% Bill Savings for Energy-Efficient House Space Heat	Space Cool	Water Heat	Appl-iances	Total Bill
New England	63%	33%	50%	35%	49%
Mid Atlantic	66%	33%	50%	33%	47%
East North Central	66%	62%	50%	33%	49%
West North Central	66%	59%	50%	34%	52%
South Atlantic	65%	62%	43%	35%	50%
East South Central	65%	62%	43%	35%	49%
West South Central	67%	62%	50%	35%	53%
Mountain North	66%	62%	50%	35%	48%
Mountain South	65%	62%	43%	35%	48%
Pacific North	65%	62%	43%	35%	63%
Pacific South	67%	62%	50%	34%	47%

Table 28. Electricity Carbon Emission Factors for Typical Houses

Census Division	Carbon Emissions (lb. CO_2/kWh.e)
New England	0.91
Middle Atlantic	1.13
East North Central	1.71
West North Central	1.90
South Atlantic	1.39
East South Central	1.69
West South Central	1.63
Mountain North	1.98
Mountain South	1.46
Pacific North	0.23
Pacific South	0.48
Total US	1.45

Notes:
1. Mountain South region includes Arizona and New Mexico. Mountain North region includes all other states in the Mountain census division.
2. Pacific South region includes California and Hawaii. Pacific North region includes all other states in the Pacific census division.

5 Bill calculation

There are two primary methods used to calculated the electric bills in the Home Energy Saver. The default method utilizes state level energy prices and the tariff method, where users can select an electricity tariff. For non-electric fuels, state level prices are used to calculate the annual bill for that fuel.

5.1 Default Energy Prices

When users first enter the Home Energy Saver site, they are assigned default energy prices based on the state in which their ZIP code is located. These default energy prices are the most recent available state averages from either 2004 (for electricity and natural gas) or 2000 (for LPG and fuel oil), summarized in Table 29. All energy price data are from the U.S. DOE's Energy Information Administration (US DOE 2000b, 2004a, 2004b). For many locations, users also have the option of selecting actual utility tariffs (see Section 5.2).

Table 29. Default Energy Prices

State	**Electricity** (2004$/kWh)	**Natural Gas** (2004$/therm)	**LPG** (2000$/gallon)	**Fuel Oil** (2000$/gallon)
Alabama	0.07550332	0.919	1.406533347	1.158065481
Alaska	0.123869546	0.358	1.68875335	1.336976196
Arizona	0.084730303	0.943	1.454940015	0.998571433
Arkansas	0.074419614	0.743	1.342600013	1.165000005
California	0.117833685	0.821	1.486906682	1.493696435
Colorado	0.083196086	0.614	1.149886678	1.285660719
Connecticut	0.116426135	1.143	1.707020017	1.368875006
Delaware	0.087991669	0.833	1.506086682	1.270404767
Florida	0.089458279	1.293	1.759993351	1.374422625

Georgia	0.079369654	0.838	1.473206681	1.349458339
Guam	0.123	1.649	1.545	1.007
Hawaii	0.18062334	2.187	2.70529336	1.449315482
Idaho	0.060768554	0.628	1.203773345	1.228797624
Illinois	0.085149595	0.733	1.091433344	1.1636131
Indiana	0.073215318	0.642	1.234826679	1.267630958
Iowa	0.090570708	0.781	0.882280009	1.395226196
Kansas	0.078174262	0.764	0.979093343	1.495083339
Kentucky	0.060845897	0.741	1.34442668	1.263470243
Louisiana	0.080924757	0.834	1.467726681	1.158065481
Maine	0.126276068	0.971	1.549013349	1.364714291
Maryland	0.080024497	0.978	1.665920017	1.418803577
Massachusetts	0.118464588	0.991	1.674140017	1.336976196
Michigan	0.0854987	0.511	1.173633345	1.334202386
Minnesota	0.080574072	0.713	1.072253344	1.231571434
Mississippi	0.081715096	0.749	1.449460014	1.191351195
Missouri	0.070626678	0.785	1.044853344	1.295369053
Montana	0.078361902	0.603	1.065860011	1.1636131
Nebraska	0.069128322	0.643	0.916986676	1.103976195
Nevada	0.097001553	0.663	1.420233348	1.483988101
New Hampshire	0.125118314	1.007	1.386440014	1.281500005
New Jersey	0.112396716	0.728	1.767300018	1.488148816
New Mexico	0.087845155	0.61	1.227520012	1.169160719
New York	0.145845539	0.986	1.62025335	1.499244054
North Carolina	0.084427936	0.953	1.443066681	1.416029768
North Dakota	0.067689121	0.637	0.990053343	1.2509881
Ohio	0.084651967	0.77	1.285973346	1.281500005
Oklahoma	0.076739676	0.737	1.086866678	1.245440481
Oregon	0.071241995	0.812	1.345340013	1.367488101
Pennsylvania	0.09655694	0.849	1.591026683	1.296755958
Puerto Rico	0.123	1.649	1.545	1.007
Rhode Island	0.121931963	0.983	1.886946686	1.346684529
South Carolina	0.080530254	0.915	1.497866682	1.478440482
South Dakota	0.076387157	0.734	0.947126676	1.239892862
Tennessee	0.068791531	0.749	1.391920014	1.511726197
Texas	0.095951006	0.741	1.411100014	1.183029767
Utah	0.072422694	0.62	1.278666679	1.219089291
Vermont	0.130738145	0.813	1.457680015	1.317559529
Virginia	0.079935881	0.998	1.583720016	1.313398815
Virgin Islands	0.123	1.649	1.545	1.007
Washington	0.063567812	0.716	1.388266681	1.539464292
Washington DC	0.081417484	1.081	1.648566683	1.068074774
West Virginia	0.062263766	0.746	1.224449373	1.224449373
Wisconsin	0.091048799	0.755	1.058553344	1.230184529
Wyoming	0.070957775	0.611	1.064946677	1.210767862
Source:	(USDOE 2004a)	(USDOE 2004b)	(USDOE 2000b)	

5.2. Bill Calculations with Utility Block-Rate and Time-of-Use Tariffs

Consumer-oriented home energy calculators are only effective if they combine careful energy analysis with energy cost information in a fashion that yields meaningful energy *bills*. Energy tariffs (particularly those for electricity) are becoming increasingly complex, as they are redesigned to encourage efficient use of energy at the margin and management of peak demand. For example, the so-called "inverted block tariffs" present the user with increasingly high per-unit electricity prices as consumption rises. "Time-of-Use" tariffs present the user with high electricity prices at times when the utility system is likely to be facing peak demands (e.g. weekday afternoons), and correspondingly low prices at off-peak times.

Most energy calculators utilize highly stylized prices (e.g. a flat cents-per-kilowatt-hour value), which fail to capture the real-world conditions facing consumers. To address this void, the Home Energy Saver site includes actual electricity tariffs, which may be selected by the user instead of default electricity prices (described in Section 5.1 Default Energy Prices of this report).

An analysis of a home on Sacramento provides an illustration of the value of more realistic electricity price assumptions. Using an actual standard residential tariff from the local utility (SMUD) results in an annual cooling electricity bill that is 22% lower than that predicted using the statewide "default" average electricity price results. Conversely, using one of SMUD's TOU tariffs results in a bill that is 32% higher than the basic SMUD residential tariff. A subsequent thermostat setback reduces the TOU bill by 18%. The results would be even more dramatic for more extreme cooling climates.

Table 30. Comparison of Energy Bills with Using Utility Tariffs

Energy price	Annual bill ($/year)	% change from previous	Cooling bill ($/year)	% change from previous	July monthly bill ($)	tariff details
state average	$1,721		$189		n/a	12.2 ¢/kWh
SMUD res. tariff	$1,462	-15%	$148	-22%	$101	summer = 8 ¢/kWh up to 700 kWh, then 14 ¢/kWh, then 15.7 ¢/kWh
SMUD RTG	$1,687	15%	$196	32%	$143	summer on-peak = 19.8 ¢/kWh, off-peak = 8.5 ¢/kWh (summer peak = 2-8 pm)
SMUD RTG w/ t-stat setback	$1,550	-8%	$160	-18%	$131	t-stat setback from 9 am to 7 pm (78 to 81 degF)
SMUD RTG w/ t-stat setback	$1,525	-2%	$154	-4%	$123	t-stat setback from 2 pm to 9 pm (78 to 81 degF)

The purpose of this module is to allow users to compare their utility bills under alternative tariff scenarios, and to assess the potential bill savings from upgrades to the house or changes in behavior.

For TOU tariffs in particular there are a special set of consumer behaviors that can currently be modeled in HES to attain energy bill savings. Examples include:

- Use of the programmable thermostat module to represent setbacks/setups, etc.
- Technical measures to reduce air-conditioning demand (efficient equipment, roof color

change, etc)
- Energy-efficiency measures in general (savings apportioned to end-use load shape)
- Shifting to a different tariff
- Shifting to a non-electric fuel

Underlying our method, utility tariff data are stored in the Tariff Analysis Project (TAP) database (http://tariffs.lbl.gov/), and TAP is utilized to provide a web service for retrieving tariff data and calculating utility bills. Currently, 177 residential and agricultural tariffs from 87 utilities in 42 states are available in the TAP database. As new tariffs are entered into the database, they are automatically made accessible to HES users. We allow users to choose among residential as well as agricultural tariffs (as some homes located on farms will utilize an agricultural tariff).

With the exception of heating and cooling (which are currently modeled on an hourly basis), the end-use load shapes are static. Thus, users cannot currently define an alternate load shape and compute savings (e.g. to represent line-drying of clothes in summer), although this capability may be added in the future.

5.2.1 Tariff Analysis Project Database

TAP was originally developed to facilitate the analysis of electricity prices for the US Department of Energy's Appliance Efficiency Standards program. The tariff database and bill calculation applications have been used in particular for the Distribution Transformers and Commercial Unitary Air Conditioning Equipment rules.

The tariff analysis infrastructure consists of two primary components: a database containing the rate structure information and related data fields, and a web interface allowing users to enter, edit and view tariffs (http://tariffs.lbl.gov/). Starting from these components, a variety of applications can be built, including bill calculator programs, batch data-processing scripts, and methods that allow TAP to interface directly with other software.

One of the key innovations in the development of TAP is the design of a data-table format that is flexible enough to accommodate the wide range of tariff structures encountered in practice. This general data-table can be thought of as a "universal tariff template". TAP currently accommodates the following rate design features for electricity tariffs:

- Fixed, energy and demand charges
- Block rates with constant or variable block sizes
- Hours charges, seasonal rates, time-of use rates

In addition to the actual rates, understanding electricity pricing requires access to information about the variety of tariffs offered by a utility, including service types, customer classes, geographic constraints etc. This additional information is built into TAP, and allows the user of the database to sample the set of tariffs according to a wide variety of criteria.

Figure 9. Tariff Detail for Standard vs. TOU tariffs (from TAP).

Standard Block Tariff

Pacific Gas & Electric Co
http://www.pge.com/
H.Q. State: California
E.I.A. Code: 14328

SCHEDULE: E-1 E-1 RESIDENTIAL SERVICE TERRITORY P

Effective: 2004-06-17

Markets Served: Residential

Service Type: Residential

Energy Range: 0 and above kWh

Demand Range: 0 and above kW

This schedule is applicable to single-phase and polyphase residential service in single-family dwellings and in flats and apartments separately metered by PG&E; to single-phase and polyphase service in common areas in a multifamily complex (see Special Condition 8); and to all single-phase and polyphase farm service on the premises operated by the person whose residence is supplied through the same meter.

Fixed Charges, ($ per month)

Annual Charges

Total Minimum Charge Rate		
Monthly Charge	$	5.00

Energy Charges, ($ per KWH)

Summer Charges

All day		
0 to 40.0 Kwh	$	0.0000
From previous value to 481.9 Kwh	$	0.1259
From previous value to 626.5 Kwh	$	0.1432
From previous value to 963.8 Kwh	$	0.1790
From previous value to 1445.7 Kwh	$	0.2097
All remaining kwh	$	0.2097

Winter Charges

All day		
0 to 40.0 Kwh	$	0.0000
From previous value to 393.4 Kwh	$	0.1259
From previous value to 511.5 Kwh	$	0.1432
From previous value to 786.9 Kwh	$	0.1790
From previous value to 1180.3 Kwh	$	0.2097
All remaining kwh	$	0.2097

TOU Tariff

Pacific Gas & Electric Co
http://www.pge.com/
H.Q. State: California
E.I.A. Code: 14328

SCHEDULE: E-7 RESIDENTIAL TOU SERVICE TERRITORY P

Effective: 2004-03-01

Markets Served: Residential

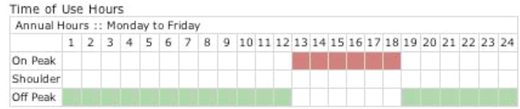
Service Type: Residential

Energy Range: 0 and above kWh

Demand Range: 0 and above kW

This voluntary schedule is available to customers for whom Schedule E-1 applies. The provisions of Schedule S—Standby Service Special Conditions 1 through 6 shall also apply to customers whose premises are regularly supplied in part (but not in whole) by electric energy from a nonutility source of supply. These customers will pay monthly reservation charges as specified under Section 1 of Schedule S, in addition to all applicable Schedule E-7 charges. See Special Conditions 10 and 11 of this rate schedule for exemptions to standby charges.

Time of Use Hours



Energy Charges, ($ per KWH)

Summer Charges

On-Peak		
0 to 481.9 Kwh	$	0.3252
From previous value to 626.5 Kwh	$	0.3252
From previous value to 963.8 Kwh	$	0.3635
From previous value to 1445.7 Kwh	$	0.3963
All remaining kwh	$	0.3963
Off-Peak		
0 to 481.9 Kwh	$	0.0952
From previous value to 626.5 Kwh	$	0.0952
From previous value to 963.8 Kwh	$	0.1334
From previous value to 1445.7 Kwh	$	0.1662
All remaining kwh	$	0.1662

Winter Charges

On-Peak		
0 to 393.4 Kwh	$	0.1264
From previous value to 511.5 Kwh	$	0.1264
From previous value to 786.9 Kwh	$	0.1646
From previous value to 1180.3 Kwh	$	0.1974
All remaining kwh	$	0.1974
Off-Peak		
0 to 393.4 Kwh	$	0.0985
From previous value to 511.5 Kwh	$	0.0985
From previous value to 786.9 Kwh	$	0.1368
From previous value to 1180.3 Kwh	$	0.1696
All remaining kwh	$	0.1696

*All prices are in US Dollars

5.2.2 User Interface for Tariff Module

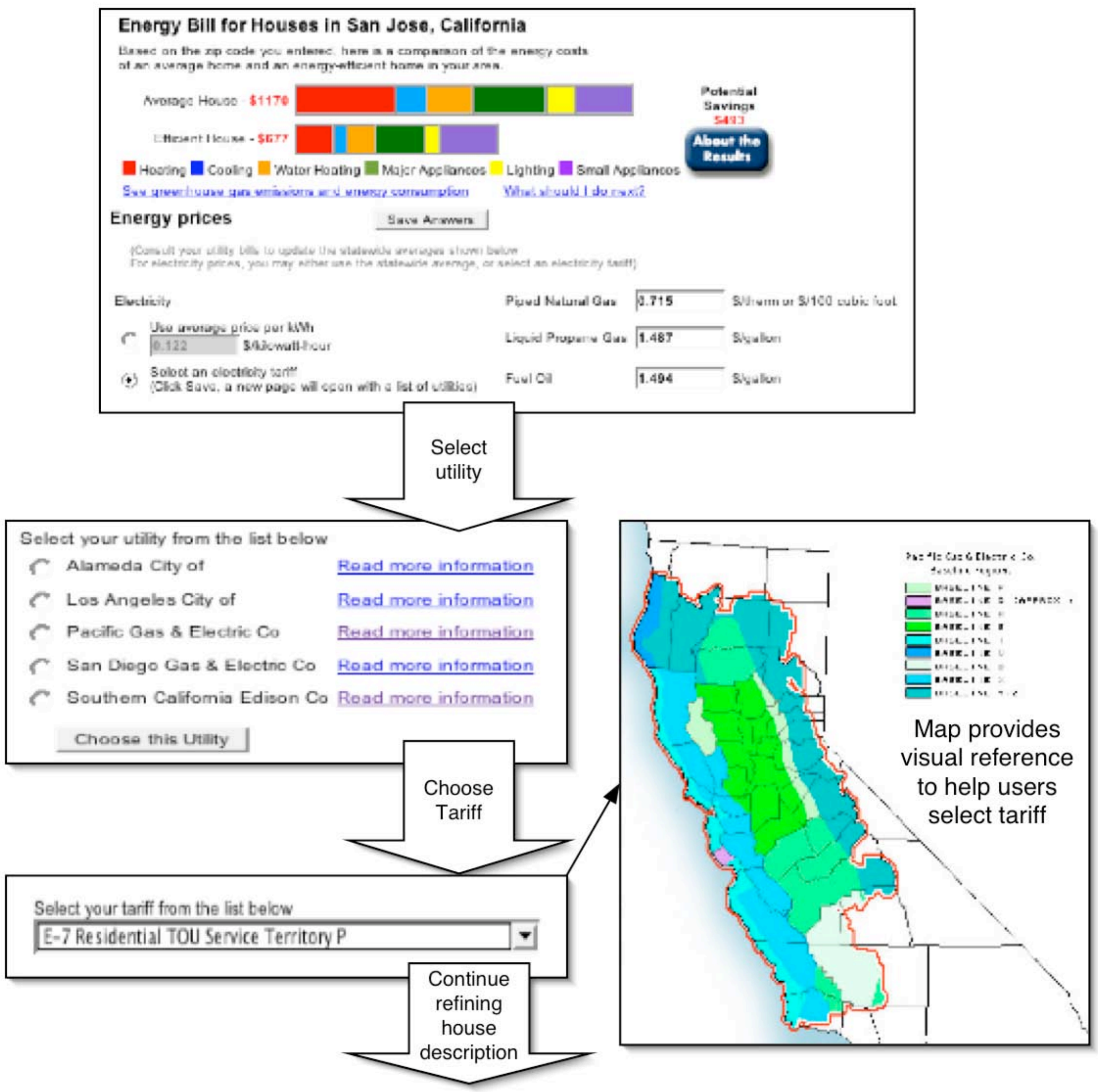
The HES user interface allows users to select a utility tariff, and to view the results of time-differentiated electricity bill calculations.

5.2.2.1 Tariff Selection

To select an electric utility tariff, users must specify their electric distribution utility, and the specific tariff they wish to analyze. The relationship between the input pages is shown in Figure 10. When editing their utility rates (on the existing HES energy prices input page), users can choose an option that starts the process of selecting a utility. Users may also make this choice to use a utility tariff rather than the state average prices from the Key inputs page. After selecting a ZIP code, users are asked to select their utility from a list of available utilities. The next page presents a list of available tariffs, based on their choice of utility[9]. After selecting a tariff, users return to continue refining their house description, or to initiate the calculation process.

Throughout this process, users retain the option to end the tariff selection and return to the default, annual-average rates, for cases where their utility is not available in the TAP database or they simply change their mind (by returning to the energy price page and selecting the radio button corresponding to the average electricity price).

Figure 10. Relevant HES Input pages



[9] Since large utilities in California typically have multiple climate zones, a link to a map showing the climate zones specific to the utility is given when available. The user can use this as a visual aid to refine their choice among the tariffs available for their utility

5.2.2.2 Presentation of Results

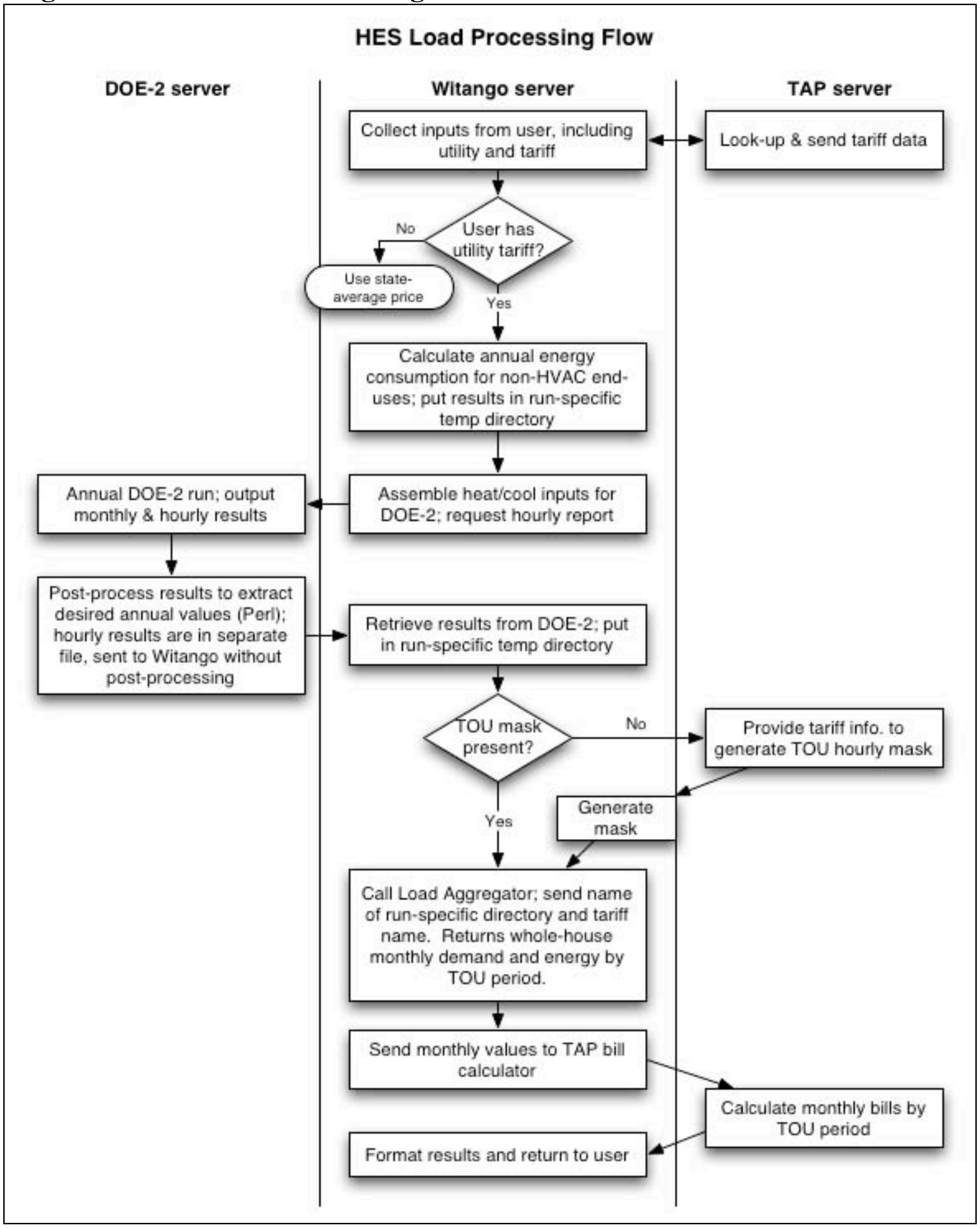
For users who choose not to use the utility tariff option, the HES result pages presents estimates of the house's annual energy consumption by end-use. Those users who select a utility tariff are provided with one or two additional results pages. Tariff analysis has added the capability to calculate energy use and peak demand by end-use within each month, and by Time-of-Use (TOU) period (for tariffs with TOU periods). As shown in Figure 5, when the user views the main results page (showing annual energy use by end-use), they are offered up to two additional choices from the blue buttons on the right side of the page. One button opens a page displaying their estimated monthly bills by end-use; the second links to a display of monthly bills by TOU period. The button linking to the monthly bills by TOU period is only present for those tariffs that contain TOU periods. These pages are small pop-up windows that display in front of the main results window. The user can close the pop-up window to return to the main results page.

5.2.3 Load Processing Algorithms

The core of the new HES functionality is a load processing "module" that translates annual electricity consumptions for several end-uses, along with hourly outputs from the DOE-2 model, into monthly utility bills.

Load processing follows the general flow shown in Figure 11. Three types of servers (DOE-2, Witango, and TAP) perform different parts of the load processing. To ensure consistency, all load calculations are based on the year 2005 calendar. There are several distinct steps necessary to transform annual electricity into monthly electricity bills. First, the non-HVAC end-uses (appliances, lighting, etc.) with similar load shapes need to be combined then allocated to a 8760-hour profile according to the appropriate load shape curve. Second, all the 8760 hourly profiles for the house (including the hourly output from the DOE-2 heating and cooling simulation engine) need to be aggregated to form the hourly profile for the house. This profile is used to identify the monthly peak demand in each TOU bin as well as the total monthly electricity consumption for each bin. These numbers are sent to TAP, which returns the monthly electricity bills. Finally these bills need to be allocated back to the individual appliances.

Figure 11. HES Load Processing Flow



5.2.3.1 Annual Energy Consumption by End-Use

HES currently calculates annual energy consumption by end-use. In some cases, consumption for multiple end-uses is aggregated to correspond to the end-uses available in the load shape files provided by the California Energy Commission (CEC). This correspondence is shown in Table 31.

Table 31. Correspondence between HES and CEC end-uses

CEC		HES	
Full name	*Abbreviation*	*Appliance*	*Category*
Water heater	sfamd	Water heater (taps and faucets)	Water Heater (other water); Major Apps (dw and cw)
Refrigerator	refri	Refrigerator	Major Appliances
Freezer	freez	Freezer	Major Appliances
Cooking appliances	cooki	Stove + oven + misc. cooking[1]	Major Apps (stove, oven); Misc (misc. cooking)
Dishwasher	dishw	Dishwasher motor + water	Major Appliances
Clothes washer	washe	Clothes washer motor +water	Major Appliances
Clothes dryer	dryer	Clothes dryer	Major Appliances
Home entertainment appliances	telev	TV + VCR + audio + other home electronics	Miscellaneous appliances
Waterbed heater	water	Waterbed	Miscellaneous appliances
Spa heater	spahe	Empty at present	Miscellaneous appliances
Spa pump	spapu	ElecSpaEnergy	Miscellaneous appliances
Pool heater	plhea	Pool heater	Miscellaneous appliances
Pool pump	poolp	Pool pump	Miscellaneous appliances
Miscellaneous appliances	misc	Remaining misc. + lighting	Miscellaneous appliances and Lighting

Notes:
1. Misc cooking includes Broiler, Drip Coffee, Percolator Coffee, Deep Fryer, Electric Fry Pan, Espresso Machine, Microwave Oven, Slow Cooker, Toaster, Toaster Oven and Electric Grill.

5.2.3.2 Utility tariff data

Information for the user-selected tariff is provided by the TAP database. These data include a unique tariff ID, and the information required to define the TOU periods for this tariff. TOU tariffs are currently available for selected utilities around the United States. Due to the complex geographic variation of some utilities in California, we developed a correspondence table to help users select their utility tariff. Within California, we generated a table that matches each 5-digit ZIP code to a specific utility service territory. This information is available at: http://hes.lbl.gov/hes/CalUtilZips.doc

5.2.3.3 Non-HVAC hourly loads

For non-HVAC end-uses, we have pre-calculated a set of fixed (i.e. household independent) end-use load shapes. The monthly allocation factor (Table 32), distributes annual energy consumption across the calendar year. This monthly energy is transformed into two 24-hour profiles using the load factors in the “2-day-type” loadshapes (for each month, average weekday and average weekend), derived from the California Energy Commission forecasting model (Appendix D). These load shape data were developed by Primen Consulting, a subcontractor to ICF, under contract to CEC and have been processed to better integrate with our data processing system, based on the same underlying load data. These load shapes are not user-variable. Finally using the 2005 calendar year to specify the appropriate day type, an 8760-hour profile is created for each end use.

Table 32. Normalized Monthly Load Factors for CEC Load Schedules

Appliance Category	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water heater	0.102	0.092	0.088	0.085	0.088	0.066	0.068	0.068	0.066	0.088	0.085	0.102
Refrigerator	0.071	0.064	0.092	0.089	0.092	0.090	0.093	0.093	0.090	0.079	0.076	0.071
Freezer	0.071	0.064	0.092	0.089	0.092	0.090	0.093	0.093	0.090	0.079	0.076	0.071
Cooking Appliances	0.093	0.084	0.084	0.081	0.084	0.073	0.076	0.076	0.073	0.092	0.089	0.093
Dishwasher	0.093	0.084	0.084	0.081	0.084	0.073	0.076	0.076	0.073	0.092	0.089	0.093
Clothes washer	0.086	0.077	0.087	0.084	0.087	0.082	0.085	0.085	0.082	0.082	0.079	0.086
Clothes dryer	0.098	0.088	0.086	0.083	0.086	0.072	0.075	0.075	0.072	0.086	0.083	0.098
Home Entertainment Appliances	0.097	0.087	0.082	0.080	0.082	0.082	0.085	0.085	0.082	0.074	0.071	0.097
Waterbed heater	0.108	0.097	0.077	0.075	0.077	0.075	0.077	0.077	0.075	0.077	0.075	0.108
Spa heater	0.071	0.064	0.092	0.089	0.092	0.090	0.093	0.093	0.090	0.079	0.076	0.071
Spa pump	0.078	0.071	0.078	0.075	0.078	0.095	0.098	0.098	0.095	0.078	0.075	0.078
Pool heater	0.081	0.073	0.081	0.079	0.081	0.090	0.093	0.093	0.090	0.081	0.079	0.081
Pool pump	0.081	0.073	0.081	0.079	0.081	0.090	0.093	0.093	0.090	0.081	0.079	0.081
Miscellaneous Appliances	0.098	0.089	0.086	0.083	0.086	0.073	0.075	0.075	0.073	0.083	0.080	0.098

5.2.3.4 Heating and Cooling Hourly Loads

For each household, DOE-2 generates annual, 8760 hourly loads. These loads are reported as several components (variables), which must be aggregated with the individual 8760 "non-HVAC" profiles to create the whole-house load. Some of the variables returned in the DOE-2 reports apply to non-electric consumption, which are ignored for the calculations described here.

5.2.3.5 TOU Mask

TOU tariffs assign each hour of each day to one of several periods. The current implementation of TAP allows three periods: peak, off-peak and shoulder. Different tariffs apply in each period.

A TOU mask is a set of three time series **P(j), F(j)** and **S(j)**, **j=1,8760**.

By definition:

- **P(j) = 1** if hour **j** occurs during a peak period, **P(j) = 0** otherwise.

- **F(j) = 1** if hour **j** occurs during an off-peak period, **F(j) = 0** otherwise.
- **S(j) = 1** if hour **j** occurs during a shoulder period, **S(j) = 0** otherwise.
- **P(j) + F(j) + S(j) = 1** for all **j.**

5.2.3.6 Load Aggregator

The core of the load processing is called the "Load Aggregator." The load aggregator is a Fortran program that runs on the web application server. Input data for the load aggregator are stored in a run-specific temporary directory on the web application server. The aggregator processing steps are shown in Figure 12. Two versions of the load aggregator are used – one for TOU tariffs and another for standard (one-period) block-rate tariffs. An auxiliary program provides the ability to dynamically generate TOU mask files, if a cached version does not exist on the web application server. These mask files are generated from a summary description of the tariff TOU periods, retrieved in real-time from the TAP server using the SOAP protocol. SOAP (Simple Objects Access Protocol) is a process that provides a way for applications running on different operating systems, with different technologies and programming languages to communicate over the internet.

5.2.4 Input Values to TAP Utility Tariff Web Service

The output of the Load Aggregator are six numbers per calendar month, corresponding to the total energy consumption and maximum demand in each of three time periods (peak, off-peak and shoulder). These values, along with identification of the chosen tariff, are sent to the TAP bill calculator using a SOAP interface. Bills are calculated for the specific tariff using the TAP bill calculation web service. This terminology is drawn from TOU tariffs, but essentially the same method applies to standard tariffs with only one time period. For non-TOU tariffs all the energy is allocated to the "off-peak" bin. Time periods are defined differently for each utility or in some cases for each tariff.

5.2.5 Bill Allocation to Specific End-Uses

Once the monthly electricity bill has been returned by the TAP web service, the monthly average (not marginal) electricity bills by end-use are estimated by allocating the whole-house monthly bill according to the relative monthly energy consumption for each end-use using Equation 37.

Equation 37

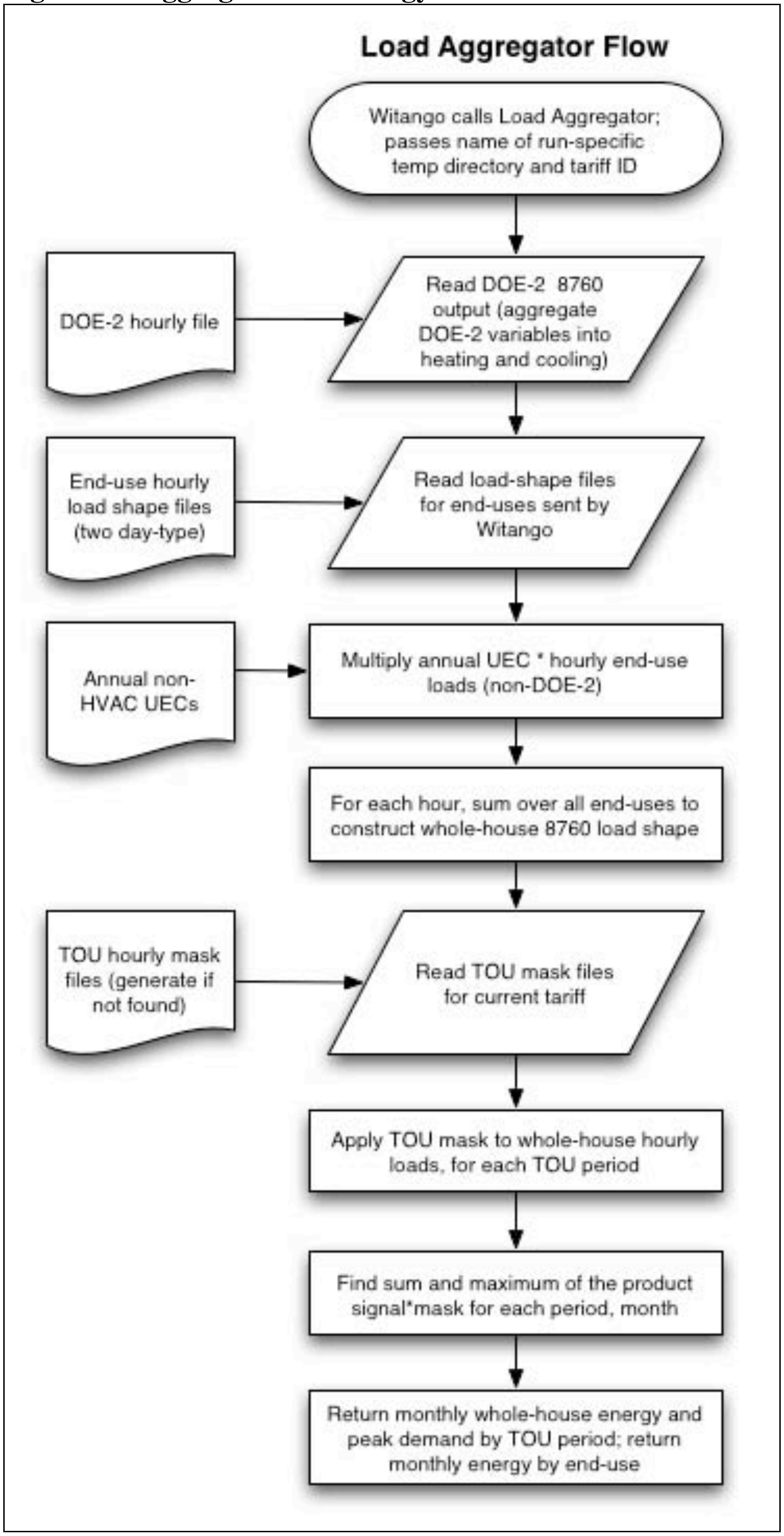
$$monthlyBill_{enduse} = monthlyBill_{house} * \left(\frac{annualEnergy_{enduse} * monthlyFactor_{enduse}}{monthlyEnergy_{house}} \right)$$

where

$monthlyBill_{house}$ = monthly bill returned by TAP service
$monthlyFactor_{endues}$ = monthly allocation factor derived from CEC loadshapes
$annualEnergy_{endues}$ = calculated energy for endues
$monthlyEnergy_{house}$ = monthly energy consumption returned by Load Aggregator

The resulting energy bills are used to show both the main results page, and additional report, the monthly electricity bill report, and where appropriate the TOU report, where monthly energy is displayed according to TOU bin.

Figure 12. Aggregation of Energy into TOU Bins



Start the Aggregator process

Import DOE-2 hourly output files (the hourly heating and cooling energy consumption).

Import non-HVAC hourly load shapes (derived from California Energy Commission load shape data).

Create hourly consumption profile for non-HVAC appliances using hourly load shapes

Combine all hourly consumption files into a single whole-house hourly consumption profile.

The TOU mask file indicates the “bin” (peak, off-peak or shoulder) to which each hour’s energy consumption should be allocated. If the tariff has been used prior to this calculation, a TOU hourly will exist. If not, a mask is generated using details about the tariffs rate structure.

After applying the TOU mask, sum consumption in each bin, and find the maximum demand for the house.

Results from the process are returned for use in calculating energy bill.

5.2.6 TAP Web Service

As noted above, the TAP database was created expressly for the purpose of storing utility tariff data and calculating customer bills using data from these tariffs. The web service consists of several functions, described below. These functions provide a client with enough data to ultimately select and generate a monthly bill from any tariff in the TAP database. In order to integrate this capability with the current HES web site, a web service interface was added to the TAP database. This web service was implemented using the SOAP protocol.

Three groups of methods provide an interface with the TAP database. These include: Utility Listing methods to allow the user to select his or her utility, Tariff Listing methods to further select individual rate schedules, and Bill Calculation methods to determine utility bills based on load data.

- Utility Listing Methods – Accept state or ZIP code data, and return corresponding utility names and codes
- Tariff Listing Methods – Return a list of available tariffs for a particular utility
- Bill Calculation Methods – Return consumption, demand and fixed charges from consumption values generated by load processing module

A complete description of the SOAP schema and sample XML syntax can be found on-line at http://hes.lbl.gov/hes/ImplementingTAP.pdf

5.2.6.1 OnTAP SOAP Server Interface Description

The OnTAP server accepts HTTP POST request in the form of well formed XML. These requested are then directed to a specific public function of the OnTAP server. Specific functions are declared in the request XML. Requests that are do not call a registered method will return the WSDL description of the OnTAP class.

The OnTAP class' public methods function as follows:

5.2.6.2 Utility Listing Methods

The following methods accept different inputs and return the same utility information output as a XML document. This document is in the form of an array of string indexed arrays values (a 2 dimentional hash table).

- *doGetUtilityListByState*: This accepts either a state's full name or it's 2 letter abbreviation as a string.
- *doGetUtilityListByZip*: This accepts a 5 digit zip code as an integer.

  The XML returned contains the following values:

- **name**: the name of the utility
- **util_id**: the internal TAP utility id
- **state**: the state in which the utility is headquartered
- **country**: the country in which the utility operates

- **url**: a link to the utility's home page within TAP
- **eia_code**: a unique code given to each utility in the United States by the E.I.A.

The key value returned for each utility is util_id, which can then used to run the tariff Listing Methods.

5.2.6.3 Tariff Listing Methods

doGetUtilityTariffs: This accept one value: util_id as a string. The XML returned contains the following values:

- **util_id**: the internal TAP utility id
- **tariff_id**: the internal TAP tariff id
- **schedule**: the name of the tariff as named by the utility
- **state**: the state for which the tariff is for
- **market**: the commercial market for which the tariff serves
- **service**: the service classification of the that the tariff delivers
- **commodity**: the commodity that the tariff covers
- **TOU**: is the tariff time-of –use or not
- **minDemand**: the minimum demand required by the customer to use the tariff as defined by the utility
- **maxDemand**: the maximum demand allowed by the customer as defined by the utility
- **url**: a link the to the tariff's description page within TAP

The key value returned for each utility is tariff_id, this is used to run the Bill Calculation Methods.

5.2.6.4 Tariff Description Methods:

doGetTOU: Returns specific time-of-use information for the tariff `$tariff_id`. This accepts 1 value: tariff_id as an integer. It returns the Time-of-use data for tariff_id as follows: An array with items for each month of the year is returned. Each item contains the following.

- **monthName**: Is the name of a calendar month
- **peakDays**: Is an array of the days of the week for which the time-of-use period apply
- **hourEnding_01 … hourEnding_24**: Is the time-of-use billing period, each of can have a value can of: onPeak, offPeak, or shoulder.

5.2.6.5 Bill Calculation Methods:

doGetMonthlyBill: This accepts 8 values, all of them integers: tariff_id, onPeakDemand, onPeakConsumption, shoulderDemand, shoulderConsumption, offPeakDemand, offPeakConsumption, and month. It returns bill information contained in a string indexed array. The bill data returned is the same for both time-of-use tariffs and standard block rate types. The values returned are as follows:

- **totalCharges**: the sum of all charges
- **consumptionTotal**: the sum of all consumption charges
- **demandTotal**: the sum of all demand charges
- **fixedTotal**: the sum of all fixed chages
- **offPeakConsumptionTotal**: the sum of all consumption charges that occur during the off-peak time-of-use period.
- **offPeakDemandTotal**: the sum of all demand charges that occur during the off-peak time-of-use period.

- **onPeakConsumptionTotal**: the sum of all consumption charges that occur during the peak time-of-use period.
- **onPeakDemandTotal**: the sum of all demand charges that occur during the peak time-of-use period.
- **shoulderConsumptionTotal**: the sum of all consumption charges that occur during the shoulder or partial-peak time-of-use period.
- **shoulderDemandTotal**: the sum of all demand charges that occur during the shoulder or partial-peak time-of-use period .
- **annualConsumptionTotal**: the sum of all other consumption charges that occur regardless of the time-of-use period.
- **annualDemandTotal**: the sum of all other demand charges that occur regardless of the time-of-use period.

DoGetYearlyBill: Is a wrapper for the doGetMonthlyBill method, it allows clients to sent a complete year's worth of inputs and return a complete year's worth of bills. It accepts and returns a 12-element array (one for each month) of doGetMonthlyBill inputs and outputs.

6. User Reports

6.1 Summary by End Use

The energy consumed by devices in each of the major end-use categories (Heating, Cooling, Water Heating, Major Appliances, Small Appliances and Lighting) is summed by utility fuel (Equation 38) and presented in three forms, as an annual bill, as energy consumed and as pollution, in the form of carbon emissions. Some end-uses have subdivisions that can also be presented to the user. This information is shown when the user has changed the inputs in the more detailed area. For example, if the user doesn't customize the inputs for Lighting, only one number, Annual Lighting Consumption will be shown. If the user gives general information about the lighting in each room of their house, then the information shown will include summaries of consumption at the room level. If a user goes further to specify actual fixtures in the various rooms, the summary report for Lighting will show this fixture level, as well as summed consumption by room and for the entire house. For a list of the devices in each end-use, see the associated calculation section above.

$$UEC_{e,f} = \sum_{d=1}^{n} UEC_{e,d,f}$$ **Equation 38**

where

UEC = Energy consumption
d = Device
e = End-Use category (e.g heating, cooling etc.)
f = fuel in utility units (kWh, therms, $\text{gallons}_{\text{lpg, fuel oil}}$)

To arrive at the final bill and pollution for each end use, the energy consumption for each fuel is multiplied by the price and emissions factor for each fuel (Equations 39 and 40). These values are summed across all fuels to get the end use bill and pollution.

$$bill_e = \sum_{f=1}^{n} (UEC_{e,f} * p_f)$$ **Equation 39**

where

UEC = Energy consumption
bill = annual bill (dollars)
e = End-Use category
p = energy price (dollars)
f = fuel in utility units (kWh, therms, $\text{gallons}_{\text{lpg, fuel oil}}$)

$$pollution_e = \sum_{f=1}^{n} (UEC_{e,f} * c_f) \qquad \textbf{Equation 40}$$

where

UEC = Energy consumption
pollution = annual pollution emissions (lbs/C)
e = End-Use category
c = emissions factor (lbs/C)
f = fuel in utility units (kWh, therms, $\text{gallons}_{\text{lpg, fuel oil}}$)

Total house values for energy, bill and pollution emissions are calculated by summing across end uses. These resulting values are displayed to the user on the results pages shown in Technical Specification of the Home Energy Saver website(Appendix D).

6.2 Carbon Emissions Factors

To arrive at the carbon emissions for energy consumed in the user's house, we multiply the annual energy for each fuel type by the carbon emissions factor for the respective fuel. Table 34 contains the state level emissions factors for electricity while Table 33 has the carbon emissions factors for all other fuels. Electricity emissions factors are from U.S. EPA's eGRID (Emissions & Generation Resource Integrated Database), which contains emissions and resource mix data for virtually every power plant and company that generates electricity in the United States (US EPA 2003). Natural gas and fuel oil emission factors are derived from U.S. DOE (1994), while the LPG emission factor is from U.S. DOE (1996).

Table 33. Direct carbon emissions from residential natural gas and oil combustion

Fuel	lb. CO2/MBtu
Natural gas	116.83
LPG	137.26
Distillate oil	161.08

Table 34. State Level Electricity Carbon Emissions Factors

State	CarbonEmissions (lb CO_2 / kWh)		State	CarbonEmissions (lb CO_2 / kWh)
Alabama	1.446297		Nebraska	1.546841
Alaska	1.291326		Nevada	1.552132
Arizona	1.175167		New Hampshire	0.708633
Arkansas	1.453267		New Jersey	0.732554
California	0.633056		New Mexico	2.137023
Colorado	2.013769		New York	0.979677
Connecticut	0.738835		North Carolina	1.292849
Delaware	1.951508		North Dakota	2.393321
Florida	1.420419		Ohio	1.844002
Georgia	1.413873		Oklahoma	1.835885
Guam	2.066944		Oregon	0.329269
Hawaii	1.716643		Pennsylvania	2.066944
Idaho	0.093223		Puerto Rico	1.234101
Illinois	1.109446		Rhode Island	2.066944
Indiana	2.152954		South Carolina	1.001701
Iowa	1.971971		South Dakota	0.893246
Kansas	1.86854		Tennessee	0.832723
Kentucky	2.228804		Texas	1.368518
Louisiana	1.386282		Utah	1.468507
Maine	0.655091		Vermont	2.095467
Maryland	2.066944		Virginia	0.056934
Massachusetts	1.372829		Virgin Islands	1.231575
Michigan	1.293151		Washington	2.066944
Minnesota	1.564727		Washington DC	0.287486
Mississippi	1.640076		West Virginia	2.656955
Missouri	1.316731		Wisconsin	2.027326
Montana	1.979393		Wyoming	1.760653

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Appendix A. Default House Characteristics

Table A-1. Characteristics based on Climate Zone

Climate zone	1	2	3	4	5	6	7	8	9	10
Year house was built	1956	1958	1960	No Zone 4	1951	1962	1968	1972	1975	1973
Number of stories	2	2	2		2	1	2	1	1	1
Heating equipment	Oil Boiler	Gas Furnace	Gas Furnace		Gas Furnace	Gas Furnace	Gas Furnace	Heat Pump	Electric Furnace	Heat Pump
Cooling equipment	None	Central A/C	Central A/C		Central A/C	Central A/C	Central A/C	Heat Pump	Central A/C	Heat Pump
Water heater fuel	Oil	Gas	Gas		Gas	Gas	Gas	Electricity	Electricity	Electricity
Adult at home during day	0	1	1		0	1	0	0	1	1
Pay for water heating fuel	1	1	1		1	1	1	1	1	1
Number of ceiling fans.	1	2	2		2	2	2	3	4	3
Year refrigerator was purchased	1993	1996	1996		1995	1996	1995	1996	1995	1997
Own a dishwasher	Yes	Yes	Yes		No	Yes	Yes	Yes	Yes	No
Own a clothes washer	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes
Foundation Type	Conditioned Basement	Conditioned Basement	Conditioned Basement		Conditioned Basement	Conditioned Basement	Conditioned Basement	Vented Crawlspace	Slab	Vented Crawlspace
Clothes dryer fuel	Electricity	Electricity	Electricity		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Stove fuel	Electricity	Electricity	Electricity		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
Oven fuel	Electricity	Electricity	Electricity		Electricity	Electricity	Electricity	Electricity	Electricity	Electricity

Climate zone	11	12	13	14	15	16	17	18	19	20
Year house was built	1968	1963	1969	1959	1971	1963	1970	1972	1966	1963
Number of stories	1	1	1	1	2	1	1	1	1	1
Heating equipment	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace
Cooling equipment	Central A/C	Central A/C	Central A/C	None	None	None	None	None	None	None
Water heater fuel	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas
Adult at home during day	1	1	1	1	1	1	1	1	1	1
Pay for water heating fuel	1	1	1	1	1	1	1	1	1	1
Number of ceiling fans.	3	3	3	1	1	3	3	1	1	1
Year refrigerator was purchased	1997	1995	1996	1997	1996	1995	1996	1992	1994	1997
Own a dishwasher	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Own a clothes washer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Foundation Type	Vented Crawlspace	Slab	Slab	Conditioned Basement	Conditioned Basement	Slab	Slab	Vented Crawlspace	Slab	Slab
Clothes dryer fuel	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity	Natural Gas
Stove fuel	Electricity	Electricity	Natural Gas	Electricity	Electricity	Natural Gas	Electricity	Electricity	Natural Gas	Natural Gas
Oven fuel	Electricity	Electricity	Natural Gas	Electricity	Electricity	Natural Gas	Electricity	Electricity	Electricity	Natural Gas

Table A-2 National Default Housing Characteristics

Default Characteristic	Value	Unit
Number of occupants aged 0 to 5	0	person(s)
Number of occupants aged 6 to 13	1	person(s)
Number of occupants aged 14 to 64	2	person(s)
Number of occupants aged 65 and older	0	person(s)
Thermostat setting of water heater	130	deg. F.
Location of water heater	garage	
Pay for water heating fuel	Yes	
Dishwasher loads washed	4	loads/week
House has clothes washer	Yes	
Clothes washer loads washed in hot wash / warm rinse	2	loads/week
Clothes washer loads washed in hot wash / cold rinse	0	loads/week
Clothes washer loads washed in warm wash / warm rinse	3	loads/week
Clothes washer loads washed in warm wash / cold rinse	2	loads/week
Clothes washer loads washed in cold wash / cold rinse	0	loads/week
First refrigerator model	General	
First refrigerator year	1986	
First refrigerator size	17	cubic feet
Second refrigerator model	None	
Second refrigerator year	0	
Second refrigerator size	0	cubic feet
Third refrigerator model	None	
Third refrigerator year	0	
Third refrigerator size	0	cubic feet
First freezer model	None	
First freezer year	0	
First freezer size	0	cubic feet
Second freezer model	None	
Second freezer year	0	
Second freezer size	0	cubic feet
Clothes dryer loads washed	7	loads/week
Clothes dryer fuel	Electricity	
Stove fuel	Electricity	
Oven fuel	Electricity	
Hours stove used per week	1	hour
Hours oven used per week	2	hours
Does stove have a pilot light	No	
Does oven have a pilot light	No	
Lighting consumption in kitchen	218	kWh/year

Lighting consumption in dining room	136	kWh/year
Lighting consumption in living room	109	kWh/year
Lighting consumption in family room	77	kWh/year
Lighting consumption in master bedroom	81	kWh/year
Lighting consumption in bedroom	73	kWh/year
Lighting consumption in closet	0	kWh/year
Lighting consumption in bathroom	192	kWh/year
Lighting consumption in hall	98	kWh/year
Lighting consumption in utility room	0	kWh/year
Lighting consumption in garage	71	kWh/year
Lighting consumption in outdoor fixtures	231	kWh/year
Lighting consumption in other rooms	0	kWh/year
Number of lighting fixtures in kitchen	2	fixtures
Number of lighting fixtures in dining room	1	fixtures
Number of lighting fixtures in living room	3	fixtures
Number of lighting fixtures in family room	1	fixtures
Number of lighting fixtures in master bedroom	2	fixtures
Number of lighting fixtures in bedroom	2	fixtures
Number of lighting fixtures in closet	0	fixtures
Number of lighting fixtures in bathroom	2	fixtures
Number of lighting fixtures in hall	2	fixtures
Number of lighting fixtures in utility room	0	fixtures
Number of lighting fixtures in garage	1	fixtures
Number of lighting fixtures outdoors	2	fixtures
Number of lighting fixtures in other rooms	0	fixtures

Appendix B. Default Energy Consumption

Table B-1 Average Annual Residential End-Use Energy Consumption by Climate Zone

Climate Zone	Space Heating (Mbtu)			Electric Space Cooling (Mbtu)	Water Heating (Mbtu)			Appliances (Mbtu)		Miscellaneous Electricity (Mbtu)
	Electricity	Natural Gas	Fuel Oil		Electricity	Natural Gas	Fuel Oil	Electricity	Natural Gas	
1	0	0	84	0	0	0	30	10	2	13
2	0	64	0	5	0	20	0	10	5	14
3	0	68	0	6	0	21	0	11	5	16
5	0	58	0	5	0	17	0	11	3	13
6	0	61	0	9	0	21	0	14	2	16
7	0	59	0	8	0	18	0	11	5	16
8	10	0	0	12	9	0	0	13	2	15
9	3	1	0	19	9	0	0	13	1	18
10	19	0	0	9	11	0	0	14	0	17
11	0	51	0	12	0	21	0	15	2	16
12	0	53	0	14	0	23	0	15	4	16
13	0	26	0	22	0	22	0	14	5	17
14	0	65	0	0	0	19	0	12	1	14
15	0	73	0	0	0	21	0	12	1	15
16	1	47	0	0	0	22	0	9	7	12
17	0	25	0	0	0	17	0	12	4	13
18	0	63	0	0	0	18	0	14	2	16
19	0	31	0	0	0	17	0	8	5	12
20	0	28	0	0	0	22	0	7	9	13

Notes:

1) Source: 2001 RECS - Averages are for single-family houses with the characteristics described in Table 24.
2) All energy consumption values are presented in Mbtu in the RECS dataset. Additionally the energy consumption output from the DOE 2.1E building simulation model is also presented in Mbtu. Therefore we retain energy consumption as Mbtu, and convert to utility units (kWh, therm, etc.) for presentation to the user, using the fuel-specific conversion factors found in Table 2 above.

Appendix C. Local Climate Parameters

Table C-1. Climate Parameters for Weather Locations

State	City	Dry Bulb to Wet Bulb ratio[10]	Duct Factor[11]	Design Heating Dry Bulb Temperature (°F)	Design Cooling Dry Bulb Temperature (°F)	Total Room Air Conditioner Compressor Hours (hours/yr)	Room Air Conditioner Use (hours /day)	(days /yr)	Inlet Water Temperature (°F)
Alabama	Birmingham	1.19	0.253	20	95	997	12	83	60
Alabama	Huntsville	1.22	0.303	10	95	957	12	80	58
Alabama	Mobile	1.20	0.120	30	95	1310	12	109	65
Alabama	Montgomery	1.21	0.167	30	100	1162	14	83	62
Alaska	Adak	1.09	1	30	85	0	2	0	40
Alaska	Anchorage	1.20	0.999	0	85	16	2	8	37
Alaska	Annette	1.18	0.998	20	85	11	2	6	45
Alaska	Barrow	1.06	1	-30	85	0	2	0	9
Alaska	Bethel	1.22	0.999	-20	85	11	2	5	29
Alaska	Bettles	1.26	0.995	-30	85	36	2	18	22
Alaska	Big Delta	1.27	0.995	-30	85	32	2	16	28
Alaska	Cold Bay	1.07	1	10	85	0	2	0	39
Alaska	Fairbanks	1.30	0.990	-30	85	61	2	30	26
Alaska	Gulkana	1.27	1	-30	85	21	2	11	27
Alaska	Homer	1.12	0.999	10	85	2	2	1	36
Alaska	Juneau	1.19	0.992	10	85	12	2	6	39
Alaska	King Salmon	1.18	1.000	-20	85	9	2	4	34
Alaska	Kodiak	1.14	0.999	10	85	3	2	1	41
Alaska	Kotzebue	1.17	0.999	-30	85	5	2	2	22
Alaska	McGrath	1.23	0.995	-30	85	21	2	11	26

[10] DB/WB ratio is the ratio of dry-bulb to wet-bulb temperature at the cooling design-day conditions. It is intended as a relative indicator of a climate's humidity during the cooling season. DB/WB ratio has been rounded to 2 decimal places for the purpose of this report.

[11] For "duct factor" a value of 0 implies that heating is never needed, thus all duct losses are assigned to cooling. A value of 1 implies that cooling is never needed, thus all duct losses are assigned to heating. Duct Factor has been rounded to 3 decimal places for the purpose of this report.

Alaska	Nome	1.16	1	-20	85	2	2	1	27
Alaska	St. Paul Island	1.02	1	10	85	0	2	0	35
Alaska	Summit	1.24	0.996	-20	85	9	2	5	32
Alaska	Talkeetna	1.20	0.999	-20	85	21	2	10	33
Alaska	Yakutat	1.13	1	0	85	1	2	1	38
Arizona	Flagstaff	1.37	0.934	0	85	151	5	30	47
Arizona	Phoenix	1.50	0.057	40	110	1648	12	137	71
Arizona	Prescott	1.44	0.496	20	95	603	7	86	52
Arizona	Tucson	1.40	0.101	30	105	1447	12	121	68
Arizona	Winslow	1.56	0.387	20	95	850	5	170	55
Arizona	Yuma	1.50	0.046	50	110	2441	12	203	74
Arkansas	Fort Smith	1.27	0.262	20	100	978	13	75	59
Arkansas	Little Rock	1.24	0.249	10	100	1009	13	78	60
California	Arcata	1.11	0.997	30	85	5	2	2	50
California	Bakersfield	1.43	0.151	40	105	831	11	76	63
California	China Lake	1.57	0.151	30	110	1546	11	141	55
California	Daggett	1.49	0.105	30	110	1059	12	88	64
California	El Centro	1.45	0.049	40	110	2281	13	175	60
California	El Toro	1.30	0.279	40	95	447	10	45	60
California	Fresno	1.42	0.217	30	105	831	12	69	66
California	Long Beach	1.23	0.218	40	90	205	9	23	72
California	Los Angeles	1.16	0.356	50	85	122	9	14	60
California	Mt Shasta	1.37	0.671	20	95	417	6	70	60
California	Oakland	1.20	0.881	40	85	84	8	11	57
California	Oxnard	1.23	0.537	50	85	302	7	43	59
California	Pasadena	1.29	0.241	40	95	396	10	40	56
California	Red Bluff	1.50	0.232	30	110	1009	12	84	63
California	Riverside	1.44	0.243	30	105	793	11	72	51
California	Sacramento	1.41	0.329	40	100	724	10	72	60
California	San Diego	1.21	0.220	50	85	69	8	9	57
California	San Francisco	1.30	0.905	40	85	84	6	14	57
California	Santa Maria	1.22	0.915	30	85	19	8	2	49
California	Santa Rosa	1.39	0.404	30	100	425	10	42	53
California	Sunnyvale	1.25	0.735	40	85	150	7	21	56

Colorado	Alamosa	1.44	0.971	-10	85	204	3	68	49
Colorado	Boulder	1.42	0.659	0	95	412	6	69	43
Colorado	Colorado Springs	1.45	0.762	0	90	381	5	76	48
Colorado	Denver-Stapleton AP	1.46	0.579	0	95	627	7	90	49
Colorado	Eagle	1.43	0.959	0	90	282	5	56	40
Colorado	Grand Junction	1.48	0.499	10	95	684	6	114	50
Colorado	Pueblo	1.43	0.535	0	100	668	9	74	51
Connecticut	Bridgeport	1.14	0.588	20	90	262	4	66	51
Connecticut	Hartford	1.19	0.628	0	95	285	6	48	48
Cuba	Guantanamo Bay	1.19	0	60	95	3446	12	287	80
Delaware	Wilmington	1.14	0.485	20	90	484	11	44	52
Florida	Apalachicola	1.14	0.092	40	90	1482	11	135	68
Florida	Daytona Beach	1.18	0.060	30	95	1281	12	107	68
Florida	Jacksonville	1.17	0.098	30	95	1198	13	92	65
Florida	Key West	1.14	0.003	60	90	2879	11	262	74
Florida	Miami	1.14	0.007	50	90	2031	11	185	74
Florida	Orlando	1.21	0.043	40	95	1597	12	133	71
Florida	Tallahassee	1.15	0.130	30	95	1110	13	85	64
Florida	Tampa	1.18	0.041	40	95	1677	12	140	69
Florida	West Palm Beach	1.14	0.012	40	95	1857	13	143	73
Georgia	Athens	1.19	0.259	20	95	829	12	69	59
Georgia	Atlanta	1.18	0.278	20	95	802	12	67	58
Georgia	Augusta	1.19	0.246	20	95	1023	12	85	60
Georgia	Columbus	1.21	0.180	30	95	977	12	81	62
Georgia	Macon	1.22	0.184	20	95	1008	12	84	61
Georgia	Savannah	1.18	0.146	30	95	1093	12	91	63
Guam	Anderson AFB	1.11	0.000	60	90	3226	12	269	79
Hawaii	Ewa-Barbers Point	1.24	0.001	60	90	1876	9	208	75
Hawaii	Hilo	1.12	0	60	85	1445	10	144	74
Hawaii	Honolulu	1.19	0	60	90	2016	10	202	74
Hawaii	Kahului	1.16	0.000	60	90	1852	11	168	74
Hawaii	Lihue	1.13	0	60	85	1814	9	202	74
Hawaii	Wake Island	1.12	0	60	90	3367	12	281	79
Idaho	Lewiston	1.47	0.540	20	95	1242	6	207	52

Idaho	Pocatello	1.48	0.809	0	95	445	6	74	45
Illinois	Chicago	1.18	0.634	0	95	426	6	71	49
Illinois	Chicago-Midway	1.22	0.510	10	90	711	4	178	50
Illinois	Peoria	1.18	0.590	0	95	522	6	87	50
Illinois	Rockford	1.13	0.689	0	90	368	4	92	47
Illinois	Springfield	1.19	0.502	0	95	651	12	54	51
Indiana	Evansville	1.19	0.426	0	95	782	12	65	54
Indiana	Fort Wayne	1.17	0.661	0	90	491	4	123	48
Indiana	Indianapolis	1.18	0.556	0	95	548	12	46	50
Indiana	South Bend	1.15	0.619	10	90	413	4	103	48
Iowa	Burlington	1.20	0.509	10	95	720	6	120	50
Iowa	Des Moines	1.22	0.590	0	95	493	6	82	47
Iowa	Mason City	1.17	0.764	-10	90	374	4	94	44
Iowa	Moline	1.22	0.589	0	95	529	6	88	48
Iowa	Sioux City	1.22	0.615	0	95	527	6	88	47
Iowa	Waterloo	1.16	0.713	-10	90	402	4	101	45
Kansas	Dodge City	1.35	0.439	0	100	758	11	69	52
Kansas	Goodland	1.40	0.599	0	100	599	10	60	48
Kansas	Topeka	1.20	0.455	0	95	631	12	53	53
Kansas	Wichita	1.30	0.383	0	100	723	12	60	55
Kentucky	Covington	1.17	0.508	10	90	593	11	54	52
Kentucky	Lexington	1.20	0.499	10	90	568	10	57	53
Kentucky	Louisville	1.17	0.407	10	95	752	13	58	54
Louisiana	Baton Rouge	1.18	0.120	30	95	1253	12	104	65
Louisiana	Lake Charles	1.15	0.114	30	95	1285	13	99	65
Louisiana	New Orleans	1.16	0.104	30	95	1244	13	96	66
Louisiana	Shreveport	1.20	0.163	30	95	1113	12	93	63
Maine	Bangor	1.20	0.784	0	85	255	2	128	43
Maine	Caribou	1.14	0.944	-10	85	79	2	40	38
Maine	Portland	1.15	0.826	0	85	179	2	90	44
Marshall Islands	Kwajalein Atoll	1.12	0	60	90	3868	12	322	82
Maryland	Baltimore	1.19	0.465	10	95	588	12	49	52
Maryland	Patuxent River NAS	1.19	0.356	30	90	770	10	77	57
Massachusetts	Boston-City	1.22	0.587	20	90	393	4	98	50

Massachusetts	Boston-Logan	1.22	0.645	10	90	305	4	76	49
Massachusetts	Worcester	1.13	0.782	10	90	124	4	31	46
Michigan	Alpena	1.19	0.888	0	90	149	4	37	42
Michigan	Detroit	1.16	0.704	10	90	313	4	78	49
Michigan	Flint	1.18	0.759	0	90	230	4	57	45
Michigan	Grand Rapids	1.18	0.739	0	90	289	4	72	46
Michigan	Houghton	1.14	0.880	-10	85	164	2	82	33
Michigan	Lansing	1.15	0.722	0	90	315	4	79	46
Michigan	Muskegon	1.17	0.741	10	85	228	2	114	45
Michigan	Sault Ste. Marie	1.14	0.957	0	85	99	2	50	38
Michigan	Traverse City	1.16	0.773	0	90	242	4	61	44
Minnesota	Int'nl Falls	1.14	0.944	-20	85	150	2	75	36
Minnesota	Minneapolis	1.14	0.717	-10	90	357	4	89	43
Minnesota	Rochester	1.16	0.768	-10	90	259	4	65	42
Minnesota	Saint Cloud	1.16	0.813	-10	90	247	4	62	43
Mississippi	Jackson	1.20	0.184	30	95	1130	12	94	65
Mississippi	Meridian	1.19	0.207	30	95	1021	12	85	61
Missouri	Columbia	1.23	0.456	10	100	686	13	53	52
Missouri	Kansas City	1.19	0.417	10	95	809	12	67	52
Missouri	Springfield	1.22	0.412	0	95	687	12	57	54
Missouri	St. Louis	1.20	0.412	10	95	757	12	63	54
Montana	Billings	1.41	0.697	0	95	391	6	65	45
Montana	Cut Bank	1.39	0.963	-10	85	199	2	100	39
Montana	Dillon	1.53	0.780	-10	90	415	4	104	42
Montana	Glasgow	1.34	0.788	-20	95	276	6	46	41
Montana	Great Falls	1.41	0.811	-10	90	309	4	77	44
Montana	Helena	1.47	0.827	-10	95	253	6	42	42
Montana	Kalispell	1.41	0.941	0	90	279	4	70	40
Montana	Lewistown	1.42	0.889	-10	95	235	6	39	41
Montana	Miles City	1.40	0.723	-10	95	403	6	67	43
Montana	Missoula	1.44	0.852	-10	95	263	6	44	42
Nebraska	Grand Island	1.24	0.582	0	95	561	6	94	48
Nebraska	Norfolk	1.27	0.580	0	95	577	6	96	47
Nebraska	North Platte	1.32	0.638	-10	100	502	8	63	46

Nebraska	Omaha	1.20	0.536	0	95	527	6	88	49
Nebraska	Scottsbluff	1.39	0.644	0	100	485	8	61	45
Nevada	Elko	1.54	0.834	0	95	349	6	58	44
Nevada	Ely	1.52	0.918	0	90	374	4	94	42
Nevada	Las Vegas	1.51	0.131	30	110	1439	12	120	64
Nevada	Lovelock	1.70	0.480	10	100	3483	8	435	51
Nevada	Reno	1.52	0.751	10	95	407	6	68	48
Nevada	Tonopah	1.52	0.608	20	95	632	6	105	48
Nevada	Winnemucca	1.55	0.682	10	100	634	8	79	48
Nevada	Yucca Flats Test Site	1.68	0.355	20	100	884	4	221	55
New Hampshire	Concord	1.19	0.793	0	90	345	4	86	44
New Jersey	Atlantic City	1.21	0.538	10	95	463	12	39	51
New Jersey	Lakehurst	1.20	0.487	10	95	589	6	98	52
New Jersey	Newark	1.21	0.492	10	95	471	6	79	52
New Mexico	Albuquerque	1.44	0.420	20	95	790	7	113	54
New Mexico	Clayton	1.47	0.475	10	95	745	7	106	53
New Mexico	Roswell	1.49	0.266	20	100	1415	8	177	59
New Mexico	Truth or Consequences	1.56	0.293	30	100	1207	7	172	59
New Mexico	Tucumcari	1.42	0.354	20	100	902	10	90	56
New York	Albany	1.19	0.724	0	90	319	4	80	47
New York	Binghamton	1.14	0.826	0	85	175	2	88	44
New York	Buffalo	1.18	0.725	0	90	283	4	71	46
New York	Massena	1.18	0.829	-10	90	245	4	61	42
New York	New York City	1.21	0.505	10	95	432	6	72	52
New York	New York-La Guardia	1.21	0.465	20	90	493	4	123	54
New York	Rochester	1.20	0.686	0	90	331	4	83	45
New York	Syracuse	1.16	0.745	0	90	324	4	81	46
North Carolina	Asheville	1.21	0.548	20	90	426	10	43	53
North Carolina	Cape Hatteras	1.10	0.264	30	90	721	12	60	59
North Carolina	Charlotte	1.19	0.312	20	95	802	12	67	58
North Carolina	Cherry Point	1.19	0.214	30	95	954	12	80	62
North Carolina	Greensboro	1.17	0.402	10	95	667	13	51	56
North Carolina	Raleigh	1.18	0.352	20	95	667	12	56	57
North Carolina	Wilmington	1.15	0.222	30	95	796	13	61	61

North Dakota	Bismarck	1.22	0.810	-20	90	354	4	89	39
North Dakota	Fargo	1.18	0.769	-20	90	397	4	99	39
North Dakota	Minot	1.23	0.855	-10	90	293	4	73	39
Ohio	Akron	1.16	0.670	0	90	319	4	80	48
Ohio	Cleveland	1.19	0.665	10	90	395	4	99	48
Ohio	Columbus	1.16	0.589	10	90	570	4	143	50
Ohio	Dayton	1.18	0.625	0	90	527	10	53	50
Ohio	Mansfield	1.17	0.646	0	90	529	4	132	49
Ohio	Toledo	1.19	0.690	0	90	402	4	101	48
Ohio	Youngstown	1.15	0.722	0	85	281	2	141	47
Oklahoma	Oklahoma City	1.27	0.296	10	100	859	13	66	57
Oklahoma	Tulsa	1.26	0.291	10	100	1009	13	78	58
Oregon	Astoria	1.17	0.987	30	85	25	2	13	49
Oregon	Boise	1.48	0.635	10	100	526	8	66	49
Oregon	Burns	1.44	0.833	10	90	296	4	74	45
Oregon	Eugene	1.32	0.803	30	90	262	4	66	50
Oregon	Medford	1.45	0.591	20	100	456	8	57	51
Oregon	North Bend	1.15	0.999	40	85	12	2	6	50
Oregon	Pendleton	1.50	0.608	20	100	420	8	53	49
Oregon	Portland	1.33	0.763	30	90	174	4	44	51
Oregon	Redmond	1.45	0.874	0	90	311	4	78	45
Oregon	Salem	1.34	0.833	30	95	253	6	42	50
Palau	Koror Island	1.10	0	60	90	3690	12	307	81
Pennsylvania	Allentown	1.18	0.620	10	90	381	4	95	49
Pennsylvania	Bradford	1.13	0.920	0	85	160	2	80	46
Pennsylvania	Erie	1.13	0.749	0	85	298	2	149	47
Pennsylvania	Harrisburg	1.21	0.527	20	95	503	6	84	47
Pennsylvania	Philadelphia	1.18	0.497	20	95	514	12	43	52
Pennsylvania	Pittsburgh	1.17	0.637	10	90	371	4	93	48
Pennsylvania	Wilkes-Barre	1.16	0.710	0	90	336	4	84	47
Pennsylvania	Williamsport	1.19	0.645	10	90	396	4	99	45
Puerto Rico	San Juan	1.13	0	60	90	3151	12	263	74
Rhode Island	Providence	1.19	0.664	10	90	237	4	59	48
South Carolina	Charleston	1.19	0.181	30	95	950	12	79	62

South Carolina	Columbia	1.23	0.226	20	100	931	13	72	61
South Carolina	Greenville	1.19	0.316	20	95	800	12	67	57
South Dakota	Huron	1.21	0.757	-10	95	460	6	77	42
South Dakota	Pierre	1.36	0.646	-10	105	459	10	46	44
South Dakota	Rapid City	1.35	0.739	-10	95	408	6	68	45
South Dakota	Sioux Falls	1.29	0.665	-10	100	436	8	55	44
Tennessee	Bristol	1.22	0.484	20	90	598	10	60	51
Tennessee	Chattanooga	1.23	0.309	20	100	913	13	70	57
Tennessee	Knoxville	1.17	0.350	10	90	767	11	70	56
Tennessee	Memphis	1.18	0.238	20	95	974	13	75	60
Tennessee	Nashville	1.23	0.326	10	100	832	13	64	57
Texas	Abilene	1.35	0.186	20	100	1165	11	106	62
Texas	Amarillo	1.36	0.419	10	95	820	9	91	54
Texas	Austin	1.25	0.099	30	100	1375	13	106	65
Texas	Brownsville	1.18	0.036	40	95	1991	13	153	71
Texas	Corpus Christi	1.19	0.052	40	100	2150	14	154	70
Texas	Del Rio-Laughlin	1.35	0.088	40	100	2305	11	210	69
Texas	El Paso	1.40	0.203	30	100	1204	10	120	62
Texas	Fort Worth	1.26	0.161	30	100	1374	13	106	63
Texas	Houston	1.18	0.100	30	95	1308	13	101	66
Texas	Kingsville	1.23	0.051	40	100	2535	13	195	72
Texas	Laredo	1.31	0.046	40	105	2051	14	147	73
Texas	Lubbock	1.34	0.306	10	95	926	9	103	58
Texas	Lufkin	1.23	0.133	30	100	1380	13	106	65
Texas	Midland	1.39	0.215	20	100	1240	10	124	62
Texas	Port Arthur	1.16	0.103	40	95	1217	13	94	66
Texas	San Angelo	1.35	0.197	20	100	1493	11	136	64
Texas	San Antonio	1.25	0.105	30	100	1351	13	104	66
Texas	Sherman-Perrin	1.28	0.180	30	100	1493	12	124	64
Texas	Victoria	1.20	0.071	40	95	1761	12	147	68
Texas	Waco	1.28	0.141	30	100	1399	12	117	64
Texas	Wichita Falls	1.32	0.205	20	105	1264	14	90	60
Utah	Bryce Canyon	1.40	0.853	0	85	386	4	96	40
Utah	Cedar City	1.48	0.651	0	95	770	6	128	48

Utah	Salt Lake City	1.51	0.518	20	100	705	8	88	39
Vermont	Burlington	1.16	0.796	0	90	216	4	54	43
Virginia	Lynchburg	1.20	0.455	10	90	611	10	61	54
Virginia	Norfolk	1.18	0.327	20	95	614	12	51	57
Virginia	Richmond	1.18	0.388	20	95	693	12	58	54
Virginia	Roanoke	1.23	0.450	20	95	617	11	56	54
Washington	Olympia	1.31	0.887	30	90	115	4	29	48
Washington	Quillayute	1.19	0.994	30	85	31	2	15	48
Washington	Seattle	1.26	0.885	30	85	105	2	53	48
Washington	Spokane	1.51	0.774	0	95	311	6	52	46
Washington	Whidbey Island	1.22	0.936	30	85	61	2	30	50
Washington	Yakima	1.38	0.745	10	95	380	6	63	48
Washington DC	Washington	1.19	0.502	10	95	560	12	47	52
West Virginia	Charleston	1.17	0.507	10	90	589	11	54	53
West Virginia	Elkins	1.14	0.785	0	85	265	9	29	52
West Virginia	Huntington	1.17	0.475	10	90	593	11	54	53
Wisconsin	Duluth	1.17	0.936	-20	85	119	2	60	35
Wisconsin	Eau Claire	1.16	0.769	-20	90	303	4	76	42
Wisconsin	Green Bay	1.16	0.801	-10	90	235	4	59	42
Wisconsin	La Crosse	1.17	0.714	-10	90	348	4	87	45
Wisconsin	Madison	1.17	0.743	-10	90	360	4	90	44
Wisconsin	Milwaukee	1.15	0.761	0	90	236	4	59	45
Wyoming	Casper	1.47	0.825	-10	95	427	6	71	43
Wyoming	Cheyenne	1.43	0.851	0	90	285	4	71	44
Wyoming	Lander	1.45	0.808	0	90	232	4	58	41
Wyoming	Rock Springs	1.48	0.901	0	90	222	4	56	40
Wyoming	Sheridan	1.41	0.802	-10	95	406	6	68	44

Appendix D. Normalized Hourly Factor by End-Use by Daytype and Month

See pdf file EnduseHourlyFactors.pdf